REPORT RESUMES

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BIOLOGY, A GUIDE FOR TEACHERS.
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DESCRIPTORS- *BIOLOGY, *BIOLOGICAL SCIENCES, *SECONDARY SCHOOL SCIENCE, BIBLIOGRAPHIES, GRADE 7, GRADE 10, GRADE 12, TEACHING GUIDES,

A STATEWIDE CURRICULUM COMMITTEE PREPARED THIS VOLUME CONTAINING TEACHER GUIDE MATERIALS FOR LIFE SCIENCE, BIOLOGY, ADVANCED BIOLOGY, AND NONGRADED BIOLOGY. A GENERAL RATIONALE FOR EACH OF THE COURSES IS PRESENTED. COURSE TOPICS AND AN EXTENDED TREATMENT OF A SAMPLE LABORATORY ACTIVITY ARE LISTED FOR EACH COURSE. THE APPENDIX CONTAINS AN EXTENSIVE BIBLIOGRAPHY, SPECIFIC LABORATORY TECHNIQUES, AND SUGGESTIONS FOR FACILITIES NEEDED TO TEACH BIOLOGY. (RS)

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BIOLOGY

A Guide For Teachers

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HUBERT WHEELER
Commissioner of Education

BIOLOGY

A Guide for Teachers

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FOREWORD

Innovative programs in the biological sciences, since 1960, have fostered this revision. A review of this publication reveals a departure from a specified outline of content as presented in the 1956 edition, to more emphasis on method and approach as reflected in the sample laboratory activities and the many teacher aids included in the appendix. It is readily discernible that this guide offers practical ways and means of implementing a laboratory-centered program. The structure of the program reflects flexibility in providing for individual differences – ranging from a non-grade course for the academically unsuccessful to the advanced course for the academically talented.

It is apparent that the Committee was fully aware of the techniques of inquiry, the innovative programs, and the laboratory-centered approach. The Committee is to be commended for organizing this guide in accordance with the recent trends in the biological sciences. The biology teachers of the State will surely find this guide helpful in implementing a more effective instructional program. The supervisory personnel of the Department and the Committee members are committed to this task. The Committee's interest and special knowledge applied to this cooperative curricular development program is appreciated.

Hubert Wheeler
Commissioner of Education

OVERALL POINT OF VIEW

OVERALL POINT OF VIEW OF THE SCIENCES

The current revision of the science curriculum has been fostered by unparalleled curricular changes, not to mention the doubling of scientific knowledge during the past decade. It is recognized by the Committee responsible for developing this guide that changes will continue; therefore, this guide has been designed to encourage teacher-experimentation with the newer methods and approaches.

BASIC TRENDS IN SCIENCE EDUCATION SINCE 1960

Recent research in science education fostered by the National Science Foundation Projects, reveals the following trends and influences:

1. The trends in elementary science, grades 1-6, continue toward the introduction of basic concepts taught under the direction of a science specialist or supervisor.

2. There is a definite trend toward emphasis on laboratory work at all levels.

3. The trend toward specialized courses at the junior high level continues – life science, earth science, and physical science are becoming predominant. There is a definite trend away from general science at the secondary level.

4. The trend toward advanced courses at the twelfth grade level continues. Research seminars and independent studies are emerging as a pattern in advanced courses.

5. The trend continues from broad coverage of subject matter to carefully selected content for study in "depth".

SCIENCE IN TRANSITION

Science education in transition since 1958 represents a transitional "from-to" process described, in brief, as follows:

1. From teacher-textbook centered instruction to a conceptual approach that develops a sense of discovery by means of a series of laboratory experiments.

2. From teacher-centered laboratory demonstration approach to pupil-centered laboratory work.

3. From emphasis on rote memorization of facts and principles to emphasis on understanding through student participation in laboratory activities.

4. From a point of view that the study of science is for only a small fraction of the students, to the belief that understanding of basic principles of the biological and physical sciences is needed for all students.

OVERALL POINT OF VIEW

Specialists in the field believe that the recent innovations in science education are far superior to the traditional course as represented by the 1956 edition of Missouri guides in science. The national programs will, no doubt, continue to influence science education at the state level. Diffusion rates of one-third and over, have been reported. There is no doubt that these programs represent the best, current thinking of leading science educators and scientists. It is reported that about 60 per cent of the science textbooks published since 1962, reflect the basic principles of these programs in a greater or lesser degree. In all cases, the orientation of the so-termed modern approaches should be toward a better understanding of the methods of investigation which implies more emphasis on pupil-participation in laboratory-centered situations with a maximum of problem-solving experiences.

ORGANIZATION

This revision is organized on the basis of the 6-6 plan of school organization rather that on the 6-3-3 basis of the 1950 edition. This change has been made to provide for a more logical continuity in scope and sequence and to avoid the inference of a "gap" between the elementary and high school courses. Grades seven through twelve are to be considered as the secondary program. This does not, however, exclude considering grades seven and eight or grades seven through nine as the junior high program.

OBJECTIVES

1. To cultivate an interest in science so that it will become a natural part of the student's life.

2. To develop skill in recognizing and stating basic problems and resolving them into component problems.

3. To develop skill in using the facilities of the science laboratory to investigate problems.

4. To develop skill in interpreting and reporting experimental investigations.

5. To develop the ability to use scientific literature as an aid in the solving of problems and for independent study.

INTERRELATEDNESS

In the final analysis, it must be recognized that psychologically, no subject is learned in isolation or that a pupil learns one thing at a time just because a bell signals the separateness of classes. Students enrolled in a science course are scheduled in at least four other courses – mathematics, social studies, language arts, health-physical education, and in some cases, a foreign language. It is recognized that individual students tend to integrate knowledge and formulate concepts on their own, but teachers should attempt insofar as possible, to relate and associate learning activities in science with other subjects in the curriculum.

TEACHING THE SCIENCE OF BIOLOGY

What will be taught each day? How will the subject be approached? What equipment will be needed? Where can help be obtained? These questions arise every day in the life of a teacher. This guide is organized to aid the teacher in his search for the answers to these questions. Since the teacher works with his administrator and is trained by a college professor, this guide is also addressed to these people. In order to aid the teacher, the administrator, and the college professor, this guide explores the philosophy of science education, student needs, course sequence, subject content, grade placement, textbook selection, guidelines, laboratory facilities, and instructional aids. These are the components considered in the development of this guide.

Various aspects of the biology curriculum present unavoidable hazards to the developers. For example, the potential content is enormous both in quantity and variety. The approach to the content offers opposing modes: such as, a general survey of the entire field versus a depth study of specific areas; an ecological theme versus a molecular theme; a technological approach versus a theoretical approach; a botanical emphasis versus a zoological emphasis; etc. The changing nature of the content argues against a static enumeration of essentials. The explosive growth of knowledge, which the extreme interest in biological research has produced, tempts the developers to include all.

What then is the answer to these very real dilemmas? Is there a right mode? Is there a way to tie down and present this mushrooming body of knowledge? Obviously, it seems neither realistic nor practical to teach biology as an "established body of knowledge". Since it cannot be presented in its totality, it perhaps can be approached through its unifying principles. These unifying principles are:

- BIOLOGY AS A SCIENCE OF INQUIRY
- UNIQUENESS OF LIFE
- INTERRELATIONS IN THE BIOSPHERE
- MAN AS A BIOLOGICAL SPECIES

HOW TO TEACH

The first principle, BIOLOGY AS A SCIENCE OF INQUIRY, serves as the philosophical approach of **HOW TO TEACH.** Since science is inquiry, and inquiry itself is a skill, shouldn't the student be engaged in developing this skill? Surely, the most effective way for him to develop a skill of inquiry is to have the opportunity to do more in the laboratory than just to verify or illustrate science concepts. In the laboratory he directly experiences the thrill of self-discovery. Simultaneously, he develops skills in formulating hypotheses and in collecting relevant data. These data are analyzed to determine if they confirm his hypotheses. It is only when the student is actively engaged in such experiences that he can appreciate and understand the nature of inquiry, its methods, potentialities, and limitations. Growing out of the development of the skill of inquiry is a development of attitudes – an attitude of objectivity rather than emotional evaluation of evidence, an attitude of support for both pure and applied research, and an attitude of responsibility towards his environment. Further, he has developed problem-solving techniques which will give him an approach to any problem throughout his life.

It follows that if the student is to participate in such an active way in the investigative process, the teacher's role in the classroom takes on a new dimension. His role becomes that of an advisor who is interested **in developing the student's skill in inquiry** and **in insuring that the experimental investigations of the student are directed towards significant ideas.** As the course proceeds, the teacher is able to let the student assume progressively more responsibility for the investigative process. Consequently, the teacher is concerned with the student's methods of scientific investigation: recognition of problems, establishment of significant hypotheses, search of the pertinent literature, design of experiments, analysis of data, and the recognition of the wider significance of his work. Since in all of these processes the student encounters difficulties, it is the particular essence of the teacher's role to anticipate the problems, and by judicious questioning guide the student to his own solution. Indeed, this is not a new role for the good teacher, only a re-emphasis of his importance and an expansion of the opportunity for creative teaching.

WHAT TO TEACH

Under the principle of the UNIQUENESS OF LIFE, the student will become familiar with the structural diversity, the biochemical unity, the reproductive capacity, and the adaptive nature of living organisms.

Under the principle of INTERRELATIONS IN THE BIOSPHERE, the student will develop an awareness that an organism interacts with members of his own species, with members of other species including both plants and animals, and with his abiotic environment at the time that these other interactions are occurring. Every organism then is taking part in a vast network of interactions. Very simply, no organism exists alone.

Under the principle of MAN AS A BIOLOGICAL SPECIES, the student recognizes that he, too, is subject to and limited by the environment in which he exists. However, man alone of all biological species possesses a unique potential; the potential of controlling and changing his environment. It is foreseeable that man will soon be able to even change his adaptive capacity. It follows that it is imperative that the student, through his biological studies, recognizes man's role and responsibility to the biosphere. In relation to this, he needs to understand the nature of scientific investigations, the importance of pure and applied research, and the **necessity of conservation.**

WHERE TO TEACH

The student's readiness for specific subject matter determines **WHERE TO TEACH**. An individual's readiness is a function of: his previous educational background, his depth in scientific training, his experience in laboratory investigation, his ability to apply mathematical skills, his skill in building logical arguments and thinking inductively, his physiological stage of development, and his own unique personality. This guide has to restrict its attention to the generalities in the above listings because the primary function of the classroom teacher is adjusting the curriculum to the individual.

Educational patterns have separated the intellectual development of the student into levels. Each level deals with the unique problems of different age groups. Each discipline has the opportunity to reach the student in each of these developmental stages. This produces the need for each discipline to select appropriate curricula and experiences for each level. This guide, which is concerned only with grades 7 through 12, recommends that there be two levels of biology – a junior high course called LIFE SCIENCE and a senior high course called BIOLOGY. These are discussed comparatively and separately in the following sections. In addition to the biology course at the senior high level, there are sections discussing other courses which are appropriate for this level; a special course for the academically slow and an advanced course for the academically capable.

LIFE SCIENCE
Grade Seven

THE JUNIOR HIGH STUDENT

The study of life science is adaptable to the characteristics of students at this age level. The students

1. are conscious of their rapid growth and body change,
2. desire to participate in the manipulative arts,
3. are very verbal – even argumentive at times,
4. desire to become useful and accepted,
5. accept reasoned explanations and conclusions,
6. desire to participate in planning his activities,
7. are interested in gathering information and developing new skills,
8. and favor the idea of self-discovery as a means of achieving their independence.

A satisfying solution in meeting the needs of this age level requires a different approach by the teacher from that required at the elementary level. Since a wider range of individual differences in interest and ability is evident at this level, the teacher should recognize the need for flexibility in method and approach.

GENERAL EXPECTANCIES

The student should learn to use some of the simpler apparatus of biology: a simple microscope, a ruler, a balance, a graduate, etc. He should learn to use the metric system and be able to understand the relationships found among the linear, mass, and volumetric units of measurement. He should begin developing skills needed to record data that are accurate, complete, and in a usable form. The student should have some experiences in interpreting his data.

PROCESSES

It is the belief of the Committee that biology should be presented as a science of inquiry and in the frame of reference of the student as the investigator. Therefore, it becomes imperative to teach the student how to investigate. Junior high science presents the appropriate time since the student, at this level, is best reached through activity supplemented by reading rather than the reverse. Nor, does the Committee intend to suggest that it is enough to illustrate subject matter in the laboratory. Rather, the essence of the course is the teaching of the processes leading to the solution of problems and an appreciation of how a scientist investigates. The scientist utilizes a logical sequence of processes: i.e., **OBSERVATION, MEASUREMENT, ANALYSIS, INTERPRETATION,** and **GENERALIZATION.** While the history of science reveals that this logical sequence has not always been employed in a chronological sequence, it is the logical sequence of these processes that is the **modus operandi** of the scientist.

The junior high biology course should be based on the use of the sequence of processes in the investigation of problems within a series of topics. Although the sequence of these processes is used in the investigation of each succeeding topic, the level of sophistication increases and the degree of structuring by the teacher decreases. In the presentation of the sequence of the processes, the student must be proficient in making observation before he measures, and he must be confident in his observations and measurements before he is ready to analyze his data. The presentation of the processes develops from the student's investigation of specific, single concept problems, but never in abstract terms. The investigation is the frame of reference for the class discussion of the processes.

PROCESSES

OBSERVATION is the first step in solving the problem under investigation. Observation is a recording of the features of a natural phenomenon which could be duplicated by a person with normal senses. Observations are to be not only demonstrable, but also relevant to the problem under investigation. A student should develop the skill of being able to distinguish between relevant and irrelevant data.

MEASUREMENT is the second step in solving the problem under investigation. Measurement is the quantification of observation. It leads to a more precise solution of the problem. It is a technique which is used in experiments of varying complexity, from those which employ no variable conditions to those which set up variation in condition(s). The relationship between the measurement of two different, but interrelated features of a phenomenon, may give additional data; such as distance/time = rate.

ANALYSIS is the third step in solving the problem under investigation. This involves critical examination of observations and measurements for similarities, contrasts, and trends which relate to the problem. This may yield patterns in data.

INTERPRETATION is the fourth step in solving the problem. Interpretation is the collation of the relevant similarities, contrasts and/or trends in the observations and measurements. This may establish a unifying principle that underlies the solution of the particular problem. Interpretation may be as simple as the answering of this question by the student; "What does this mean to me?".

GENERALIZATION is an extension of the unifying principle, from a particular problem which has been solved, to an expanded set of phenomena. If further observations in the expanded set support the applications, the principle becomes a hypothesis.

INSTRUCTIONAL PROGRAM

COURSE CONTENT

We recognize that there will always be variations in the quality and content of textbooks available for courses in junior high life science. Furthermore, the actual order in which topics will be studied will be governed not only by the text used, but also by the time of year, background and interest of the student and the experience and judgment of the individual teacher and school system. Consequently, these recommendations are of general nature, attempting to outline only areas of study and emphasis, but not sequence and specific content.

SUGGESTED AREAS OF INSTRUCTION

1. The Planet Earth as a Place to Live

This area should review and emphasize those physical characteristics of the earth and solar system which relate directly to life. The purpose is to get the student to recognize the physical conditions that direct and limit living organisms. The concept that the physical conditions are not static and change through time should be introduced, but not elaborated upon.

2. Life – Similarities and Diversities

In this area we believe that life should be viewed from the standpoint of two important concepts. **Firstly,** living organisms share many features in common, such as chemical characteristics, ability to create complex chemical compounds, and the ability to utilize energy in a directed manner. **Secondly,** diverse organisms with different capabilities live under diverse conditions.

3. Continuity and Variation in Living Things

It is the intent of this area to emphasize at a simplified level the concepts of reproduction, the mechanisms of inheritance and the manner in which the diversity of life has originated.

4. Plant and Animal Associations

This area should emphasize the existance of various natural communities and the interdependences of living things to one another and their physical environment: food cycles, symbiotic relationships, and man's relationship, particularly as concerns conservation and exploitation of natural resources.

5. Health and Hygiene

The concept of health should imply the individual's ability to live in the physical and biological environment. Hygiene, then, is an applied area of science which should maintain or improve the health of an organism. The concepts of hygiene should be related whenever possible to sound biological information – human biology.

COMPARISON OF UNIFYING PRINCIPLES AT JUNIOR HIGH AND SENIOR HIGH LEVEL

The following is a series of guidelines to help distinguish life science at the seventh grade level from biology at the tenth grade level. Each of the four unifying principles have been broken down into basic categories. The tenth grade level directives are based upon the assumption that the student already possesses the seventh grade skills. If this is not the case, then it will be necessary to build those skills first and hopefully also be able to develop some of the tenth grade skills. The increased maturity of the tenth grader and his broader experiences should enable him to develop the seventh grade skills more rapidly.

JUNIOR HIGH LEVEL	SENIOR HIGH LEVEL
I. BIOLOGY AS A SCIENCE OF INQUIRY	
A. PROBLEMS	
1. Largely teacher initiated; leading to an appreciation of how a scientist investigates biological phenomena.	1. Teacher initiated leading to development of *models; student defined, applied, and/or extended.
2. Student investigated.	2. Student investigated.
B. SKILLS	
1. Most emphasis on physical skills.	1. Continuation of development of physical skills.
a. Qualitative observation; distinguishing the relevant from the irrelevant.	a. Qualitative observations; leading to categorization.
b. Quantitative observation; making accurate measurement with simple instruments. (Requires lots of practice.)	b. Quantitative observation; determining validity of measurements and extending skills with more sophisticated instruments.

**A scientific model is an explanation of phenomena which enables an organization of the observations into a meaningful pattern until a better model is hypothesized.*

2. Introduction to mental skills. a. Teacher directed analysis via teacher-student dialogue. b. Teacher assisted interpretation and generalizations.	2. Most emphasis on mental skills. a. Analysis arising from class discussion via student-student dialogue. b. Student interpretation and generalizations.
C. EXPERIMENTS	
1. Only single concept.	1. Largely single concept, but many can be multi-concept.
2. Duration one period or less.	2. Duration may be short or lengthy.
3. Two-thirds of class periods should be laboratories.	3. Three-fifths of class periods should be laboratories.
4. Experimental design: a. Teacher designed. b. Analysis of errors in terms of source of experimental errors.	4. Experimental design: a. Student designed experiments in addition to teacher designed. b. Analysis of errors on a mathematical and statistical basis.
5. Conclusions concrete and produced as a result of a learned skill.	5. Abstract conclusions created by students from their analysis of the data.
D. EVALUATION IN TERMS OF STUDENT ATTAINMENT: THE STUDENT HAS . . .	
1. PHYSICAL SKILLS to make measurements with a fair degree of accuracy with simple instruments.	1. PHYSICAL SKILLS to make measurements accurately with a variety of instruments.
2. ANALYTICAL SKILLS a. to record data in prepared tables. b. to rank order phenomena on the basis of one property. c. to interpret graphs recognizing increasing and decreasing relationship.	2. ANALYTICAL SKILLS a. to design and use data table for specific experiment. b. to rank order phenomena on the basis of two or more properties. c. to interpret graphs mathematically.
3. REASONING SKILLS a. to recognize that the data provide evidence b. to recognize cause-effect relationship and how these are substantiated by experiments.	3. REASONING SKILLS a. to recognize that a specific set of data does not represent all available evidence. b. to recognize cause-effect relationship; to realize the inability to always determine which is the causal agent, such as structure-function; to avoid technological interpretations.

c. to follow a sequential argument.	c. to follow and/or create a sequential argument.
4. GENERALIZATION SKILLS	4. GENERALIZATION SKILLS
a. to make a simple concrete conclusion.	a. to make concrete and abstract conclusions.
b. to apply the conclusions of an experiment to a narrow and closely related problem.	b. to apply the conclusions of an experiment to a broad spectrum of related problems.
5. BEHAVIORAL SKILLS	5. BEHAVIORAL SKILLS
a. to be able to work with other people to accomplish a job.	a. to be able to relate his performance in terms of the class in accomplishing a task.
b. to develop a sense of responsibility toward equipment and time.	b. to recognize the relationship between the condition of equipment and reliability of data.
c. to be able to follow short, concise experimental procedures with minimal direction.	c. to be able to follow sequential experimental procedures with minimal direction.
d. to be able to use an assigned book to find specific materials.	d. to be able to locate an assigned topic in appropriate books.
e. to be able to support ideas with evidence.	e. to be able to support ideas even though there is conflicting evidence.
II. THE UNIQUENESS OF LIFE	
A. DIVERSITY	
1. Morphological-function diversity exemplified by a few local and familiar specimens in terms of their gross external characteristics.	1. Structural-function diversity exemplified by numerous, varied specimens in terms of their external and internal characteristics.
2. The role of morphological-function in the adaptation of organisms to their environment.	2. The role of structural-function in the convergent, divergent, and radial adaptation of organisms to their environment.
B. UNITY	
Similarity of processes of living organisms which differentiates them from non-living matter.	Similarity in mechanism of life processes and their dynamic equilibrium.

SAMPLE LABORATORY ACTIVITY

*SAMPLE LABORATORY NARRATIVE

The teacher announces that the students are going to do an experiment with sowbugs. From the questions asked by the students, the identity of the sowbugs are established as "pillbugs", "roly-poly", "those things under the rocks", or some sort of identification to everyone's satisfaction. As she takes roll, etc. the students are to read the introduction to the experiment in their text and answer the review questions. The teacher then announces that the students are to work in groups of five. There is much whispering and signals as to who is going to be in which group, but this is quickly settled.

Tch: What does respond to stimuli mean?

Std: To act or jump when something outside yourself happens.

Tch: Good, can someone give an example?

Std: We run out of class when the bell rings.

Tch: Yes, your example fits John's definition, "to act when something outside yourself happens." What did John mean by "outside yourself"?

Std: Environment.

Tch: Then respond to stimuli means that an organism acts when something happens in its immediate environment. What kind of an environment does the sowbug live in?

Std: Dark. Under rocks.

Tch: What is it like under rocks? You should be able to think of some characteristics even if you have never lived under rocks.

Std: Dark, damp. Full of crawly things.

Tch: What is the problem you are going to investigate today?

Std: What a sowbug does.

Tch: Yes, you are to observe a sowbug to see **what?**

Std: What it will do when it has a light or dark place to go.

Tch: The problem also increases tactile stimuli. Did anyone look up tactile in the dictionary? (A flurry of reaching for dictionaries mixed with a few groans.) What is it Rose?

Std: Touch. Do we have to touch them?

Tch: Yes, and without squealing. Squealers flunk. (Various girls squirm and giggle, but sensing the firm purpose behind the teacher's attempt at humor, they settle down.) What are the variables?

Std: Touching, dark-light, and dry-wet.

**Patterns and Processes of Science: Brock, Paulsen and Weisburch, D.C. Heath, Publisher*

Tch: Why do you have to do three experiments? Why can't you test for touching, light, and dry at once?

Std: No matter what the sowbug did, you wouldn't know which thing had caused the sowbug to act.

Tch: Why wouldn't you?

Std: In order to get a cause-effect relation, only one condition should be varied at a time. The others have to be kept constant.

Tch: What variable must **not** be present? (No immediate answer. They are told to re-read the procedure which specifies silence.) The teacher allows the students to move from desks to the flat-top tables where the light-dark boxes are set up. She then tells one person from each group to come after the sowbugs. As she removes the damp towels to get the sowbugs, there is some additional squealing, but with appropriate remarks by the teacher about courage, etc. the sowbugs are distributed. Then, the fun begins as the students try to place the sowbugs at the central door right side up. Teacher reminds the students that they need to be quiet.

Std: They are crawling out of the box.

Tch: Try not to interfere, but don't let them escape.

Std: He's dead. Another member of the group: "No, he isn't. You touched him."

Std: Don't stick them with a pencil. (The five minutes are over and the counting begins.)

Std: Hey, there are three in the light, and only two in the dark.

Std: There are only four. We lost one. No, here he is under the towel. (The boxes are set up for the next trial with virtually the same problems and comments.)

Std: (At the end of the second count.) Why are there more bugs in the dark the second time than there were the first? (The experiment continues until the end of the period, and the students are asked to complete the discussions of the results and conclusions. The next day the teacher opens the discussion by asking if there are any questions.)

Std: Weren't the sowbugs supposed to go into the dark?

Tch: Why do you hypothesize that you would find them in the dark?

Std: Because it is dark under a rock.

Tch: Good. Since their natural environment includes darkness, you hypothesized that they would be in the dark. What do you mean by "suppose"?

Std: The sowbug should have been in the dark.

Tch: Then you don't mean that the sowbugs have to do something? What did John mean when he said the sowbugs were "supposed" to be in the dark?

Std: That he thought the sowbugs would go into the dark.

Tch: John has brought out an extremely important point. As biologists, we may think that the plants or animals may do (or behave) in a certain way, **but** they don't **have** to react to a stimulus. They are not "supposed" to react to a stimulus. You, as a scientist, test them under controlled conditions to see if they do or don't react. Your hypothesis is your guess, and only your guess, about what the sowbugs do. What did your sowbugs do, Alvin?

Std: In the first trial, three were in the dark and two were in the light. In the second trial, four were in the dark, and one in the light.

Std: But, that's not what we got. We had two in the dark and three in the light.

Tch: Yes, the results are different. What can we do to see better what the sowbugs did?

Std: Put everybody's on the board.

Tch: Fine, will you make a table for the data of all the groups on the board? (The data are assembled.) What was your hypothesis about the response of the sowbug to light and dark environments?

Std: I hypothesized that the sowbugs would choose the dark.

Tch: How do you account for the differences in your observations?

Std: There was a lot of noise. Somebody bumped our table. The sowbugs were scared. The floor of the box was not like their natural ground. (The data from the wet-dry experiment were put on the board and discussed.)

Std: How do we know that the sowbug went to the wet because it was wet? Maybe they went into the wet because it was cooler.

Tch: Why do you think it would be cooler?

Std: The towel is wet. Since evaporation is a cooling process, the wet part would be cooler.

Tch: Would you like to test your hypothesis? We can do that tomorrow.

It is hoped that the students begin to appreciate the difficulties involved in working with living organisms. Also, they should develop some of the techniques necessary in experimenting with living organisms. The student should begin to connect the behavior and physical structure of an organism with its environment. The behavior of a sowbug in its response to choice of conditions parallels the conditions which are present in its natural environment.

The sowbug is otherwise called pillbug, roly-poly bug, wood lice or land isopods. (See: Buchbaum, R. **Animals Without Backbones,** p.268-5). They can be found under logs, bricks or rocks. An old wooden plank can be laid flat in some corner of the schoolyard a week before the experiment and should provide an adequate supply. In case of dry weather, water the collecting area. Earthworms or millipedes might be substituted.

INTRODUCTION: Ans. 1. are highly organized. 2. grow. 3. metabolize.
4. respond to stimuli. 5. are adapted to their environment.
6. reproduce.

respond – react
stimuli – message from surrounding, such as a noise or an internal message, such as hunger.

I. PROBLEM:

To handle living animals and observe their behavior

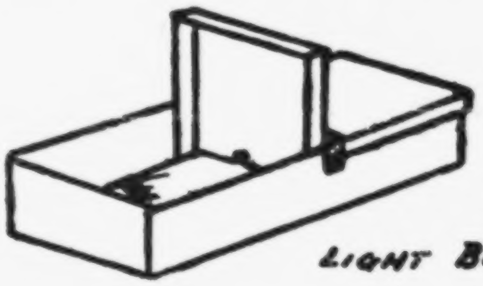
To determine the response of the sowbug to the tactile stimulus, to a choice of light or dark environment and to a choice of wet or dry environment

To relate the response of an organism to a laboratory stimulus to its natural behavior in an environment

II. MATERIALS AND EQUIPMENT: clocks, 5 sowbugs/team, light box, moisture box.

The boxes can easily be made from shoeboxes.

Light Box: Line one-half of the box with black paper. Cut lid in half. Cut one-half to serve as a partition across the width of the box. On the bottom edge of this half, cut a small hole (1 cm x 1 cm). Tape this half of the lid into place as a partition. Put tape along bottom edge to prevent light leakage, except for small hole which will serve as a passageway for the sowbugs. Tape the cut edge of the other half of the lid to the top edge of the partition in a "hinge" fashion. Allow side and end "flaps" of this half of lid to remain so that they overlap the sides of the box and, therefore, prevent light leakage



LIGHT BOX

Moisture Box: Simply place damp towels in the bottom of one-half of a shoebox. Cover with lid.

III. PROCEDURE:

1. Students work in teams of four.
   Silence is necessary in order not to disturb sowbugs.
   (This experiment has been tested on exceptionally intelligent ninth graders with the variation that the students design and set up their own apparatus.)
   Results from this have indicated that it is necessary for the teacher to make the boxes. However, it is interesting to do the experiment unstructured.

IV. RESULTS:

A new skill in observing living organisms

A relationship between the laboratory behavior of an organism and its natural behavior and environment

A review of variables and conditions

V. DISCUSSION OF RESULTS:

1. The sowbug is small and looks like a piece of dirt. Also, the back is hard and protects the soft inner parts.
2. Normally, the sowbug would tend to run or avoid light. The sowbugs would be in a damp environment. (Some students may suggest that the wet is cooler. If so, provide them with thermometers and let them check their hypothesis.) Chief sources of error are unnatural environment, student noise and vibrations.

VI. CONCLUSIONS:

1. tactile, light, and moisture. 2. light. 3. wet. 4. properties.
5. closely fitted (Note: students should add "to its environment" after the parentheses.)

INTRODUCTION:

Are you alive? Can you prove it? As a scientist, you must look for evidence. As an observer, you have seen many forms of matter, and, as a scientist, you have sought similarities among them. Once you have found a set of phenomena with similar properties, you have been able to classify them into categories.

Now it is slightly different. You intuitively know the category of living things. The problem is to recognize what properties the members of this category have in common. You need to test your intuitive hypothesis that living forms of matter have common properties. You determined a list of such properties in Experiment 39, "Patterns and Processes". Your list was modified by class discussion. List these properties below:

____

____

____

____

This list is a working hypothesis. You may want to modify it. Indeed, authors of textbooks do differ in the wording of these properties. If you realize that all of the properties are closely related, you will see the commonality of the lists. You have been concerned in the laboratory and other lessons with these properties. This experiment tests the response to stimuli by the organism, the sowbug.

SAMPLE LABORATORY ACTIVITY

Review what these words mean.

respond____

stimulus (i)____

Scientists have agreed that one property of living things is their ability to respond to stimuli. This ability is sometimes called irritability. How does a scientist determine if an organism responds to a stimulus? He experiments with a particular organism. He presents one stimulus (the variable) to the organism under controlled conditions and observes the behavior of the organism.

J. Henri Fabre is very famous for his careful observations of insects and the style with which he wrote of his insects. One example of his investigations is, what stimuli caused the cicada to cease "singing". He found that if the observer approached the cicada and could be seen by the cicada, be insect ceased to sing. On the other hand, noise did not bother the cicada. Fabre would approach a singing cicada without being seen and then talk or clap his hands and the cicada kept on singing. Fabre even went so far as to arrange for a gunner to lead the town cannons. The cacadae sang overhead in the branches of the trees. Fabre and five observers counted the number of singers and noted the volume. The cannon boomed like a thunderclap. The singing of the cicadae continued uninterrupted. Fabre concluded that the cicadae responded to the stimulus of the sight of a man but did not respond to noise.

You are to determine the response to stimuli by the sowbug. The sowbug may be found under rocks or logs in your backyard. They feed on dead vegetation under the logs. State your prediction of what you think the response of the sowbug wlll be to the choice of a light or dark environment.

____

____

I. **PROBLEM:** To determine the response to the stimuli; tactile, light and water by the sowbug.

II. **MATERIALS AND EQUIPMENT:** 5 sowbugs, 1 moisture box, 1 light box.

III. **PROCEDURE:** Observe the behavior of living organisms. Handle them carefully. In each experiment, the conditions are controlled, except one variable. Therefore, you must be very careful not to jar the table or make loud noises.

1. Very carefully touch a sowbug. Observe its behavior. Pick up a sowbug. Again observe and record.

2. Carefully place the five sowbugs in the center of the light box. Be sure that none is on its back. Let the box and sowbugs sit **undisturbed** for five minutes. After the five-minute interval, record how many are in the lighted portion and how many are in the dark portion. Repeat the experiment.

3. Now place the five sowbugs in the center of the moisture box. Put the lid on the box and wait five minutes. Remove the lid and count the number of sowbugs in the wet area. Repeat.

IV. RESULTS:

1. Response to touch

____

____

____

2. Response to light.

	Number of Sowbugs		
	Time	Light	Dark
Trial 1			
Trial 2			

Further observations

____

3. Response to moisture

	Number of sowbugs	
	Moisture	Dry
Trial 1		
Trial 2		

Further observations

____

____

V. DISCUSSION OF RESULTS:

1. The reaction to touch by a sowbug could be a means of defense. How do you think this response could aid the sowbug against its enemies?

____

2. The sowbug lives under logs, rocks, and bricks, etc. The sowbug breathes by means of gills. The sowbug feeds on decayed vegetation. Do your experimental results correlate (agree, disagree) with the natural behavior of the animal?

____

Did the response to light seem in keeping with an animal which lives under logs?

____

____

How does the response to moisture agree or not agree with what you would expect from an animal which breathes through gills?

____

Were there any differences between the two trials? ______________________

How do you account for these? ______________________

____

VI. CONCLUSIONS:

1. Sowbugs respond to the stimuli ______________ ______________
   and ______________
2. Sowbugs move toward the ______________(light, dark).
3. Sowbugs move into a ________ (dry, wet) area preferably.
4. The responses to light, moisture, and touch by the sowbug are ______________ of behavior of the sowbug.
5. The properties of behavior of the sowbug are ______________(closely fitted, unrelated).

GENERAL BIOLOGY
Grade Ten

GRADE PLACEMENT

The grade placement of this course is currently under the investigatory eye of many educators – college professors, administrators, and classroom teachers. The need for this inquiry is due to experimental placement of biology in the ninth grade which resulted from collegiate pressure for extended intellectual background, parental pressure for increased curricular offerings at the secondary level, administrator's search for a "prestige" course to substitute for general science, and personnel desirous of teaching certain courses. Now, after biology has been introduced at the ninth grade, the question arises as to whether or not the shift was beneficial to the student.

When the grade placement is viewed unemotionally, the basic question to be answered is what academic preparation and maturity level should a student have in order to have a meaningful experience in a biology course appropriate for the senior high level?

What intellectual demands would be entailed by a biology course appropriate for the senior high level? (1) Biology uses the disciplines of physics, chemistry, and mathematics to explain "living" phenomena. (2) Scientific inquiry involving such a mixture of disciplines is built upon verbal abstract reasoning. (3) The content includes the extremes of the concepts of time, size, organization, interrelationship, and energy. (4) Human sense organs are far too limited an observatory instrument to use and must be extended through a variety of mechanical instruments. (5) The need for supportive laboratory skills at the start of the biology study is imperative if appropriate experiences are to be meaningful to the student.

Viewed through the eyes of an experienced classroom practitioner who realizes that LEARNING TAKES TIME, the above list is staggering. The student should have had PRIOR to biology: (1) laboratory experience which is investigatory in nature in all three sciences, (2) experience in handling quantitative data, (3) experience in arranging data so that patterns can be observed, (4) experience in the use of scientific measurements, scientific terminology, causation, etc., (5) experience which enables him to understand the significance of millions of years of environmental change.

The course should, naturally, encompass the unifying themes of biology and be so structured that the student's inquiry does not have to end with the termination of the school year. If the student has an accumulation of "answers to nature's problems and mysteries", he is not a student of biology as it is known today. The major problems facing humanity between now and the year 2000 will be biological in nature. Recognition of this is essential to the survival of the species and the "answers" are barely on the horizon. Taxonomy and anatomy will need to be extended and clarified through the newer disciplines of biology if the answers are to be found. The future citizenry will have to supply the initiative, incentive, patience, and monies for further research for the continued advancements in the biological sciences. If this advancement is to become a reality, present-day students need to have experienced the nature of the scientific methods of inquiry and the complexity of biology at a very mature level – capable of grasping the full significance of their future role as citizens in an ever-changing environment.

If the current available curricular materials, the science background needed by the students, and the course goals are considered, **then the earliest possible grade placement for ANY STUDENT to study biology should be in the 10th grade.** This rationale is in accordance with the grade placement recommendations made by the Biological Science Curriculum Study Group.

STUDENT DESCRIPTION

The tenth grade student is apparently at a crossroad because the greatest number of dropouts occur during this grade. In each discipline the materials are handled analytically, abstractly, and individually. As a result, intellectual skill weaknesses become apparent to the student. The teacher is challenged to develop the intellectual skills through the medium of course content. In biology, the teacher's role is magnified because this will be the last exposure to science for many students, and the teacher's task is to make each student realize the importance of biological science to the future of man. In one way, science lends itself to captivating the student, for in no other discipline can he so readily experience the thrill of discovery. In another way, it is quite intellectually demanding, for where else does analysis of problems transcend so many disciplines?

Society presents the student with three major problems. As a teacher, one needs to be aware of these problems in planning student experiences. The first of these is TIME. The independence of the student in the tenth grade is being asserted and he is assuming the major management of his time. Many areas are seeking his time, dates, cars, religious activities, school, athletic organizations, family activities, and not the least of these, school assignments. It will take awhile for him to learn to use his time wisely. Secondly, the opportunity to develop MANUAL DEXTERITY has been reduced by time-saving mechanical devices which demand only switch-flipping skills. Manual dexterity is important in the science laboratory. The student may need to handle an instrument numerous times before his movements are fluid and precise. Thirdly, the pressure to receive high grades as a key to future opportunities is being forced on the student. As a result, the student will have difficulty in distinguishing between effort for knowledge and effort for grades.

COURSE CONTENT

There is no one plan of organized content. Biological content can be organized in various ways to emphasize different themes. There are, however, major themes which enable the development of the relevant modes of biology. These themes are summarized as follows:

I. BIOLOGY IS A SCIENCE WHICH SEEKS TO UNDERSTAND THE NATURE OF LIFE THROUGH INQUIRY

This theme speaks through the major questions which have been posed to "life." In some cases the men posing the questions should be allowed to tell of their thrilling experiences; the manner in which the problem was investigated, the evidence which was collected, and the interpretation of this evidence. In other instances, the student will be seeking the answer through his own endeavors. The student will thus gain an insight into the uncertainty, incompleteness, and changing nature of science. He will become aware of the role of biology in our changing technology, agriculture, medicine, and management of natural resources.

II. LIVING FORMS CHANGE THROUGH TIME

This theme, like the first, ties together the concepts of biology. When the change in life forms are viewed historically, the internal and external mechanisms become apparent. The internal mechanisms include sexual reproduction, chromosomal abberrations, point mutations, and gene pools. The external mechanisms are competition, isolation, and other environmental factors. With these mechanisms species are maintained and new life forms established. The student perceives that any life form is not only a product of change but also is a factor in the process. The diversity of the life forms are a product of similar biochemical processes.

III. THE RELATIONSHIP OF ORGANISM AND ENVIRONMENT IS COMPLEMENTARY

This theme also has its roots in the orderly process of change. It includes the interplay of "life" and "environment" at all levels of biological organization – organelle to biosphere. The fluctuation of life is a response to its environment – not to be overlooked is the reciprocal relationship because living organisms which also affects a change in their environment. This phenomena is well illustrated by man's drastic effects on his environment as well as the fascinating unfolding of ecological succession. The response of life to its environment and other organisms is also seen in their behavior patterns. These patterns range from fixed to flexible ones. The significance is enhanced through the realization by the student that his behavior and limitations are biologically rooted. He should be cognizant of the fact that "society" is an expression of group behavior.

IV. STRUCTURE AND FUNCTION ARE COMPLEMENTARY

This is perhaps the oldest recognized concept of biology and for many years it was the unifying theme. The concept of function emerges from the belief that each structural part has a role in maintaining the whole. The newer emphasis in biology is to relate structure-function without assigning a causal-effect relation. However, the function of a structure is dependent upon the types, arrangement, and activity of the parts composing the structure. Again, this concept applies to all organizational levels. The assemblage of subparts and subfunctions into a whole, demands a means for adjustment to changed conditions. The concept of regulation extends this capacity to explain more permanent adjustments of the whole at specific developmental stages or after prolonged variation from the normal physiological condition.

These four major themes should be considered in selecting and organizing the content of a basic course in general biology. The newer approach to content selection emphasizes the understanding of basic principles through the techniques of inquiry, laboratory activities, and related readings, rather than the acquisition of a mass of information gained in the traditional "follow-the-textbook fill-in-the-blanks" approach. Content selection is made not only in respect to needs and ability of the learner but also in keeping with the training of the teacher and the growth of knowledge in the subject field.

A change in biological content is reflected by a speculation made by Joseph Jackson Schwab, Professor of Natural Science, University of Chicago, "If a biologist today were to go into outer space and stay there for four years, he would have a desperate time catching up with his fellow biologists when he returned. After eight years of absence, he would hardly be able to communicate with them."

The Committee based its decision not to present a specific outline of content in this guide on the premise that students must acquire the techniques of inquiry which enables them to relate new knowledge as it develops to the major themes or principles of the subject field. Therefore, specific selection of content based on needs and ability of the students becomes the responsibility of teachers individually and/or collectively within a school system.

SAMPLE LABORATORY ACTIVITY

INTRODUCTION

In the following pages you will find a narrative description of some laboratory investigations. It is hoped that you will be able to visualize the student's activities as if you were in the "driver's seat". While for many years it has been accepted philosophically that one learns by personal experiences, all types of such experiences do not yield the same result. In recent years, all types of student experiences have been scrutinized and the more profitable ones, for the student, are becoming apparent. As a result of a profitable experience a student should develop mental skills and modes which enables further intellectual growth. The laboratory investigations described herein are examples of such profitable experiences.

While perusing the pages, you will be cognizant of the characteristics of a profitable experience for a student. The exercises described provide an opportunity for the student to be active in many ways – emotionally by the arousement of his curiosity, manually by manipulation of various apparatus, mathematically by a quantitative approach, mentally by making his own interpretations. Further, the student is encouraged to extend his intellectual growth by making predictions, by speculating on related problems, and by determining the validity of his findings.

LABORATORY INVESTIGATIONS

"What are those things?" "Eggs." "They feel funny." "Let me see!" "Gosh, they're soft." "Gee! . . . oh, they have no shells." "Silly, how could you have a raw egg without a shell?" These comments were heard on the day the students saw an egg in a beaker of liquid sitting on the table of each squad. The eggs marked the beginning of a series of inquiries concerning exchange between a living system and its environment. Each class period, for the next ten days, the students weighed the eggs and recorded any significant changes. Although no class time was given to the discussion of the investigation at this time, the students talked among themselves. They became concerned over the egg's increases and decreases in mass. They kept trying to figure out how the shell could have been removed. Was it really a raw egg?

Following the last measurement, the students were asked what questions they had concerning the egg. Questions tumbled forth: How was the shell removed? Why did the mass of the egg change? Why didn't the egg smell if it was raw? How could the egg be so tight one day and by the next be limp? Since a lab assistant had removed the shells, he explained the use of dilute HCl to dissolve the shell. "Well, what kept the egg together if the shell were completely gone?" Through a sharing of bits of knowledge the students decided the egg was really a one-celled structure and as such possessed a plasma membrane which would hold the egg's contents together. Someone suggested the odors were retained within the membrane and could not escape. A relationship was suggested between changes in mass and the egg's tightness or limpness. The tightness was then related to an increase in the contents and the limpness to a decrease in contents. The skeptics questioned the easy solution because the egg had been in water and why would it take in water on some days and release it on others. Wild possibilities sprang forth: on hot days water went in and on colder days water went out, water always went in but the momentum of its inner movement exceeded the egg's capacity and the water reversed its direction. Eventually the students agreed on the following assumptions concerning the egg's change in mass:

1. Any particle leaving or entering the egg must pass through the plasma membrane.
2. The membrane was not affected by the removal of the shell and therefore would function similarly to any other membrane.
3. The egg was placed in a liquid. (The students first listed water but no one could positively prove that it was water so they selected a less restrictive term.)
4. Any change in mass would have to be a result of either a gain of matter within the egg or a loss of matter within the egg.
5. Any gain in matter would have to come from the external liquid and any loss in matter would have to be lost from the contents of the egg.

SQUAD A

DATE	HOURS			
	1	3	5	6
1/26	61.16	60.62	60.30	60.10
1/27	62.33	62.66	62.45	62.91
1/28	64.59	63.86	64.22	65.12
1/31	67.40	66.42	63.87	63.42
2/2	60.60	59.61	59.74	59.82
2/3	61.38	61.57	61.50	59.00
2/4	61.60	58.81	61.40	60.85
2/7	61.3	62.17	62.62	62.40
2/8	64.41	64.95	65.22	64.90

SQUAD B

DATE	HOURS			
	1	3	5	6
1/26	67.77	66.53	65.68	65.67
1.27	68.45	68.22	67.88	68.61
1/28	68.22	68.68	67.61	68.24
1/31	68.645	67.22	63.89	63.57
2/2	58.23	57.7	56.92	57.13
2/3	59.477	60.01	59.41	60.01
2/4	60.24	60.5	59.3	60.63
2/7		59.83	57.79	61.31
2/8			63.10	63.61

SQUAD C

		HOURS			
		1	3	5	6
DATE	1/26		52.2	54.45	55.74
	1/27	60.1	60.12	60.4	60.96
	1/28	63.3	63.7	63.94	64.51
	1/31	69.0	67.5	65.4	65.3
	2/2	62.3	61.8	62.37	62.4
	2/3	64.7	64.3	64.85	64.6
	2/4	64.8	64.9	69.92	64.7
	2/7	66.6	66.4	65.85	66.6
	2/8				

SQUAD D

		HOURS			
		1	3	5	6
DATE	1/26	66.84	67.32	67.80	68.00
	1/27	69.60	70.22	70.70	71.15
	1/28	73.25	73.62	74.25	73.95
	1/31	77.16	76.25	73.40	73.31
	2/2	68.23	68.32	68.60	68.00
	2/3	69.62	69.99	70.00	69.92
	2/4	70.00	70.08	70.00	70.16
	2/7	71.4	71.02	70.06	71.18
	2/8	73.0	73.42	71.03	71.11

In order to give the students an overall perspective of the egg's change in mass, a composite data sheet was handed to them. This sheet contained the mass of the four squad's eggs taken during each class period for the ten-day period. An analysis of the data was in order. A graph was suggested and two students were asked to design a possible graph on the board. The drawing of the *y* and *x* axis was easy, but there ensued immediately an argument over what units should be used and on which axis. The two, assisted by other class members, decided upon a graph showing the rate of change in the egg's mass. Time therefore would be on the *x* axis and mass on the *y* axis. It was decided to plot mass to the nearest 0.05 gm since this corresponded with the accuracy of the balance. The unit for the time axis proved more difficult. There were four different recordings for each day. Day was selected as the unit. The instant one of the boys began to plot the data another problem reared its head. There was a mass for each period for each day. Which should he use? The average mass was determined to be the most reliable.

At this point the boys returned to their seats and the students were asked how they would attempt to interpret the four curves and what they anticipated finding. One student said that an egg was an egg and he expected all curves to be similar. Another suggested the curve should be described in terms of mass gained or lost. One student who had been looking at the data wanted to know what was happening when the egg remained at the same mass. The possibilities of no particle movement or equal particle movement in both directions were postulated by the students. The question which stopped everyone was asked by a lad who had plotted out one curve and wanted to know just why there was such a very sharp drop in mass at one place. He just couldn't understand how water could have two entirely different effects on the same object. He had always thought that one substance would have exactly the same effect on another and obviously there were two entirely different effects. Opposite sides of the argument drew up their forces and verbal attack began immediately. The battle ceased when one boy said if you took a piece of paper and tore it in half and held a burning match to one-half of it and it burned, what would happen if you held the same burning match to the other half? Water should have the same effect and a horizontal line meant the effect had ceased. Craftiness entered into the situation and after a few well-chosen questions by the students they discovered the fact that the liquid was not always water; it was a 7 percent potassium nitrate solution part of the time. Then the question of which liquid caused which effect was raised. The students returned to the data and decided they could not determine this. Another set of eggs would have to be set up and knowledge of which solution was being used would solve the question. Was there a faster method? Was there a method by which one could directly observe the effects of content change? It was suggested that a leaf of Elodea could be viewed microscopically and each solution could be added and the effect observed. This was done and the differences noted.

The students were then asked to write up the experiment, postulate the days on which the liquid was changed from one type to another, what particle or particles were moving in and out, and why the two liquids had different effects. Since the students had not read or discussed any literature concerning diffusion through membranes, their postulations ranged from erroneous concepts; such as, "the egg gained weight when water passed through the membrane and lost it when the potassium nitrate displaced water in the egg," to highly imaginative ones such as "potassium nitrate could be a highly absorbant solution which absorbs wastes and other materials from the egg." Nevertheless, abundant ideas came forth which required validation through a literature search and stimulated interest in the complex topic, "diffusion."

The problem of diffusion was being attacked from a different front during the days of egg weighing. The students were involved in a study of the cell and its maintenance of "life." After a search of the literature and a class discussion of the findings, it was decided that a cell had to exchange substances continually with its environment. This exchange must be selective and controlled functionally by the cell membrane. The students posed various questions pertaining to particle exchange: "Would the exchange be related to an increase in cell size?" "Would the membrane through which the particles pass, increase in size at the same rate that the volume of that cell increased?" "Would the amount of surface area affect the rate of particle entry?" The following take-home problem was given the students to determine an answer to the question: "Would an increase in volume affect the amount of available surface area through which substances may enter a cell?"

PROBLEM

Will an increase in volume affect the amount of available surface area through which substances may enter a cell?

ASSUMPTIONS

1. Cells occur basically in three forms: cubes, cylinders, or spheres.
2. Mathematical model using the cube, cylinder, and sphere would be easier to use than an actual cell.
3. If the surface area and volume were increased in a definite pattern, the relationship between the two could be determined.
4. A ratio of surface area/volume would be the best analytical method to determine the pattern of any relationship.

HYPOTHESIS

State your own.

PROCEDURE

Use the formula given in the table to compute the surface area and volume. The values of *s*, *r*, and *h* are the same in any one trial.

Begin with them equaling "1". Each successive trial increases the value of *s*, *r*, and *h* by multiplying the last value by 2. Compute the values for four different sized objects of each type.

FORMULAS

	SURFACE AREA	VOLUME
CUBE	$6s^2$	s^3
CYLINDER	$2 \pi r^2 + (2r)h$	$\pi r^2 h$
SPHERE	$4\pi r^2$	$4/3 \pi r^3$

DATA

Record computations in an organized form.

ANALYSIS

Compute the surface area/volume ratio for each shape for each size. Record in organized form.

INTERPRETATION

Is there a pattern in the ratios as you look at the smallest and go toward the largest in each shape? Is the pattern a constant one? Is the pattern the same for all shapes?

EXTENSION

1. What prediction would you make concerning the surface area/volume ratio of an enlarging cell? Does this agree with your original hypothesis?
2. Speculate on the following:
   a. Do you think the surface area/volume ratio might affect the rate of materials entering a cell? Would the affect be the same for materials leaving a cell?

   b. Do you think the percent of volume which is penetrated would be affected by the surface area/volume ratio?

   c. Do you think the surface area/volume ratio would set a maximum size to a cell?

Upon completing the laboratory, students compared their findings during a class discussion. In general, the hypothesis recognized that both the surface area and volume would increase, but that the volume would increase more rapidly. One boy thought the sphere would show an even more marked change than the other two models. Based upon his findings, the student refuted the statement. Another student conjectured that when the findings are applied to a living or former living system, there would be a determining factor not present in the mathematical model – elasticity of the outer membrane. Most students saw the decreasing pattern of the ratio, many observed "that the ratio decreased approximately 50 percent each time the cell doubled in size." However, after making this statement, since it was contrary to his original supposition, one stated, "this refers only to this particular laboratory." Another student took her predictions and immediately put them to work. She said, "The rate of materials entering a cell would be affected by the ratio of surface area to volume, because as the ratio goes down, the efficiency of intake goes down. Since the ratio is the real determinate of the speed of the intake, there must be a point where the intake will stop and the cell will cease to grow. For instance, if you take a trial when s=16, then the ratio would equal approximately 0.4, if the next one is doubled and s=32, then the ratio would equal approximately 0.2, and if s=64, then the ratio would equal approximately 0.1. We aren't sure where this point is, but you can see that at some point the efficiency for intake will get so low that the cell will stop growing." Others suggested that the size of the materials or the thickness of the membrane might affect the rate of entry. Others thought that the rate of entry was constant and hence would set the maximum size because the cell's food needs would exceed the ability of the membrane to provide it. One student even suggested that after the cell reached the size where it wouldn't supply the inside, it would divide to restore a proper surface area/volume ratio.

SAMPLE LABORATORY ACTIVITY

The diversity of opinion concerning rate of entry into a cell presented an opportunity for another laboratory experience. Again, a simplication of the problem was achieved through the use of one liquid and non-living system.

RELATIONSHIP OF CELL SIZE TO A SUBSTANCE ENTRY

PROBLEM

Will the cell size affect the rate of a substance entering a cell? Will the cell size affect the availability of this substance to the total contents?

ASSUMPTIONS

1. The cube is the easiest shape with which to work and its findings would hold true for both the sphere and the cylinder.
2. The red liquid will penetrate the cube at the same rate on all exposed surfaces.
3. The rate of entry can be determined by the linear penetration divided by time.
4. The percent of the volume penetrated is equal to the volume of the total cube minus the volume of the cube which was not penetrated.
5. To determine rate, time must be a variable.
6. The experimenter's technique will furnish reliable data.

HYPOTHESIS

State your own.

PROCEDURE

1. Cut a cube with sides of 1 cm and another with sides of 4 cm from the agar block provided.
2. Place each cube in the red liquid (a 1 percent $NaOH$ solution with phenophthalein) for the time assigned your squad. (The students selected a time spread of 1 -16 minutes.)
3. Remove the cubes at the appropriate time, cut in half and measure the linear distance from the edge of the cube inward that was penetrated by the red liquid. Record to the nearest 0.5 mm.

DATA

Record the results of all squads in an organized form.

ANALYSIS

Base your analysis on the composite data.

1. What is the rate of linear penetration (mm/min) for each cube at each time period?
2. What is the percent of the total volume of each cube which was penetrated during each time period?

INTERPRETATION

1. What effect does cell size have on the rate of entry of the red liquid?
2. What effect does cell size have on the availability of the red liquid to the total cell's contents?

EXTENSIONS

1. What prediction would you make concerning the effect of size on the rate of entry and the percent of the volume which was penetrated by the red liquid?
2. Speculations:
    a. Would substances other than the red liquid enter in a similar pattern?
    b. List factors which might cause deviations from the predicted effect.
    c. Devise an experimental setup to check your prediction of one deviate.

The majority of students expected a faster rate of entry into the larger cube. They reasoned that a larger cube would have a larger surface area and therefore a faster rate of entry. With the results of the investigation laying before them, they were quite hesitant to accept them wholeheartedly. The rate of entry for each time period was essentially the same for both cubes. However, the longer the cubes were exposed to the red liquid, the slower the rate of entry. The percent of volume penetrated was always greater in the smaller cube. One excited girl noted that the rate of entry at four minutes and sixteen minutes was the same, but the percent of volume penetrated was less at the sixteen-minute time period. She postulated that a certain time saturation must have been reached. Some students volunteered to try to determine when this occurred.

Looking at the rates of entry, one student observed the immediate rapid rate of entry was followed by a gradual decrease until there was no change at all. The consensus of opinion was that the increase of the red liquid inside the cube occupied space and produced a resistance to more red liquid entering. When the rate of entry became constant, evidently some of the red liquid was leaving because the percent of penetration was actually reduced at the sixteen-minute time period.

A student finally summed up the whole experiment by saying that the surface area/volume ratio directly affects the percent of the volume penetrated but does not affect the rate of entry. The rate of entry is a function of time. At first, the entry is very rapid and then it gradually decreases with the passage of time until it becomes a constant.

The last two investigations were concluded about the time as the original egg investigation. An effort was made to tie the three investigations together. The students returned to the graph of the egg's mass and noted its rapid increase followed by a constant mass. This pattern was noted also in the rapid rate of entry of the red liquid into the agar blocks followed by its gradual decrease until it became a constant. Further mystery was interjected by posing the question as to why particles would enter into an egg or an agar block. There was always some student who remembered enough to say that particles moved from where they were numerous to where they were less numerous. Why then didn't chairs move from the room into the corridor where there were none? The students, by this time, were thoroughly perplexed, but curious and a very profitable literature search followed. The size of particles, the chemical properties of particles, the energy of particles, the concentration of particles, each was found to play a role in diffusion. The total picture was considerably more complex when the students added to this picture the semi-permeability of the cell's membrane. The completion of the unit did not stop the student's inquiry. They have tried the egg in a variety of substances: sugar solutions, vegetable oils, molasses. They have tried various concentrations of solutions. The experiences of the students did enable them to form some models, to make use of these models, and to continue their intellectual probing even after the investigations were closed. The students did not feel as if they knew all of the answers, but rather as if they had the tools by which they could continue studying the problem.

BIOLOGY FOR THE ACADEMICALLY UNSUCCESSFUL NONGRADED

POINT OF VIEW

RATIONALE

Biology texts are, in most cases, written for the average or above average tenth grader. What then is the fate of the non-achieving student taking biology? He may be assigned to a regular course in which he may become a disciplinary problem, withdrawing behind a wall of silence, or he may drop out completely. Or, he may be shuttled into a "remedial" biology class where he is subjected to a course which merely reduces the terminology and laboratory work. In short, because of the problems inherent with teaching the academically unsuccessful, and the lack of material designed for this student, he is often the forgotten member of our school population.

A recent biological curriculum study has recognized the need for a specific curriculum for different levels of student ability. Each ability level requires materials which provides opportunities for successful scientific inquiry. Each curriculum emphasizes the same basic biological concepts. The curriculum entitled **Biological Science: Patterns and Processes,** formerly called **Special Materials,** was developed by BSCS as a method for presenting the science of biology to the academically unsuccessful student. Its structure and content have been developed to give special consideration to the needs and abilities of this type of student. By tailoring laboratory and reading materials to the level of these students, **Patterns and Processes** exposes them to the excitement of scientific inquiry and enables them to grasp the important biological concepts. For this reason, it is believed that this course should be considered for inclusion in all high schools.

NOTE: The remainder of this section refers specifically to **Biological Science: Patterns and Processes.** Currently, few curricula are available for this type of student and this text represents the best existing plan. Until more curricula become available for the academically unsuccessful, this can serve as a standard.

STUDENT IDENTIFICATION

Since **Biological Science: Patterns and Processes** is specifically designed for the academically unsuccessful, it is important that every effort be made to accurately identify this student. The course is designed for the truly academically slow student and not for underachievers, disciplinary problems, or emotionally disturbed students of average or above average ability. Average students become bored with the simplicity of the material and the slow pace set by such a class; whereas, the truly slow student thrives on it.

The Differential Aptitude Test has been successfully used as an identifying instrument for slow learners. Students who rank below the 40th or 50th percentile on the DAT (VR + NA) are of the ability level for which this course was designed.

Other factors such as IQ, previous academic performance, teacher recommendation, and many others have been used in combination with or without the DAT. The methods used for finding the slower learner are not important as long as they prove reliable. The thing of real importance is that an effort be made to identify these students and help them achieve some degree of academic success.

TEACHER DESCRIPTION

The instruction of the slower achiever is a task which potentially produces more frustrations than a regular class.

The success of a course for the academically unsuccessful student depends heavily upon the classroom teacher. If this person does not WANT to teach this type of student, even the best curriculum has little chance of success. Why then, is it often the practice to assign remedial classes to the newest or youngest teacher? This is not fair to the teacher or students. If care is taken in selecting the students for **Patterns and Processes,** then equal consideration should be given to selection of the teacher for these students. The teacher should possess the following:

1. A desire to teach the slow student, based on the belief that teachifg these young people is important and rewarding.

2. A belief that these students can profit from a course of the type that utilizes the laboratory approach to teach basic biological concepts.

3. A good background in biology and the philosophy of teaching laboratory oriented biology.

4. A realistic estimate of the expected outcomes.

CLASS SIZE

The responsibility for maintaining satisfactory class size is basically the task of the administrators and counselors. In keeping with the need for individualized instruction, a class of 15 students or less should be considered a necessity for assured success in this type of program.

INSTRUCTIONAL PROGRAM

COURSE ORGANIZATION

The materials for **Patterns and Processes** consists of the teacher's manual and individual paperbound, consumable student manuals.

The teacher's manual is unique in that in one volume it presents the entire sequence of the course in detail. It gives the teacher suggested methods for developing concepts, for handling student discussions, and for introducing and summarizing student activities. Possible student questions and approaches for each problem are also included. The teacher's manual is a guide for every aspect of the year's work. Since these students have a very low reading level, they are usually discouraged the first day of class by the large textbooks. To avoid this frustration, the **Patterns and Processes** student manuals are designed to be presented one page at a time, which prepares the student for each reading or laboratory activity. If these pages are kept in a loose-leaf notebook along with class notes, data laboratory sheets, and other class materials, each student will develop his textbook as the year progresses. This unusual feature, coupled with reading materials prepared on a seventh grade level, makes the student manual one which a student can easily understand and enjoy.

BSCS **Patterns and Processes** is divided into five topics of basic biological concern. A brief discussion of the content of each of these topics follows:

I. ECOLOGICAL RELATIONSHIPS

Consideration of ecological relationships has been chosen as the introductory topic since the student's environment surrounds and affects his daily activities. The student conducts population studies both in the laboratory and in the school yard, observes an ecosystem that he has set up, and watches how organisms respond to their environment; thus, the student is able to understand basic ecological concepts. This understanding opens the way for consideration of such environmental problems as air and water pollution. In this way, the student is given the opportunity to apply what he has learned from his observation to problems that directly concern man and his environment.

II. CELL ENERGY PROCESSES

Where do living organisms get the energy to stay alive? How do they take in energy? How is this energy used? These are a few of the questions that confront students when studying cell energy. Some of the areas that students investigate to gain insight into these questions are the role of digestion and diffusion in food utilization, cell structure in plants and animals, and stored energy and its measurement in food and its ecological relationship examined from a standpoint of energy exchange. The concepts developed in Topics I and II help the students understand why the increasing world population is a serious problem.

III. REPRODUCTION AND DEVELOPMENT

Almost all students are interested in the subject of reproduction and development. This topic capitalizes on this interest by allowing the students to carry out a careful program of investigation into the reproduction and development of a variety of living organisms.

To stimulate discussion and curiosity, the students are introduced to the theory of spontaneous generation and asked to decide just how true they think this theory actually might be. The ensuing discussion leads to a discussion of asexual reproduction. In the course of events, the student becomes aware that all organisms do not reproduce asexually and this leads naturally to questions concerning sexual reproduction. When this point is reached, the student begins a series of laboratory activities dealing with reproduction and development in plants and animals. This work gives the students an opportunity to observe first-hand the development of several organisms – from single eggs to complex multicelled organisms. The comparison of frog, chick, and plant development climaxes this series of laboratory exercises.

As the students study the development of frog and chick, they begin to relate what they are observing to their own development. This opens the door for the study of human reproduction and development. This unit leads into this subject very smoothly and should be studied in the degree in which the student's desire and ability allow.

IV. GENETIC CONTINUITY

To get the students interested in genetics they are asked to examine several human characteristics. (The student is not aware that some of the characteristics studied are controlled by heredity.) Upon completion of this examination, they are confronted with the question, "Why do some of these characteristics occur in a predictable fashion?" Examination of probability and its relationship to inheritable traits followed by laboratory activities involving crosses of Drosophila (or the wasp Mormoniella) help the students develop a reasoned answer to this question. The topic is concluded with a discussion of the relationship between DNA, genes and chromosomes, and a consideration of the role of meiosis in heredity.

V. THE EVOLUTION OF LIVING THINGS

The focal point of this topic is an examination of the theory of natural selection as a mechanism of evelotion. After working with ecological relationships, cell energy, reproduction and development, and genetics, the students will have developed sufficient understanding of a variety of biological concepts to allow them to apply these concepts in considering how living things change or evolve. Because of the necessity for extensive application of concepts developed early in the year, the subject of continuous genetic adaptation of organisms serves to unify the year's work. It effectively reviews the past learnings and helps the student develop a basis for analysis of problems in the future.

SAMPLE LABORATORY ACTIVITY: The Change in a Yeast Population.

Materials Needed for Teams of Four People

- 10 test tubes
- Aluminum foil (heavy)
- 250 ml beaker
- Balance (sensitive to 0.1g)
- 250 ml graduated cylinder
- Stirring rod
- Source of heat (Bunsen burner)
- Spatula or scoopula

Preparing the Yeast Growth Medium

Each team of four should prepare:

Yeast extract (bacto-yeast extract)	0.5 g
Potassium phosphate, monobasic	0.4 g
Glucose	8.0 g
Peptone	1.0 g
Distilled water	200.0 ml

Add the dry materials to the total volume of water. Dissolve by heating, over a low flame while stirring constantly. When properly dissolved, the medium is clear and slightly yellow in color. (If it is cloudy you have done something wrong. Start again.)

Preparing the Test Tube Cultures (each team of four)

Pour 15 ml of the medium into each of 10 test tubes and cover with an aluminum foil cap. Sterilize the tubes by placing them in an autoclave or pressure cooker and following the directions of your teacher.

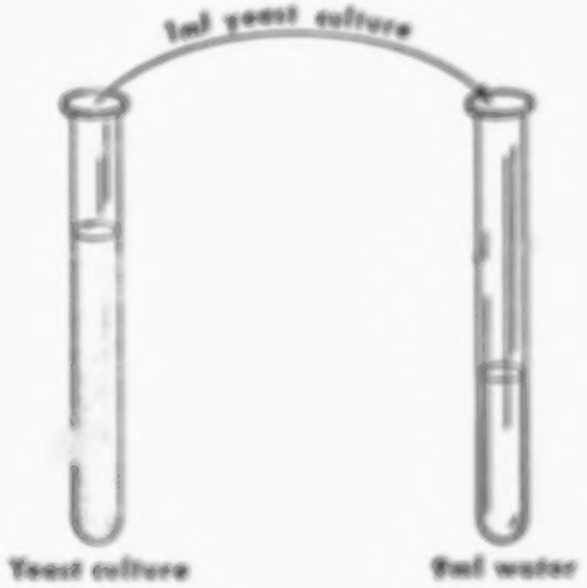
Number your test tubes 1 to 10 with a marking pencil. Label each tube with a team symbol.

Take a small square of aluminum foil and place on it 9 grains of dry yeast, all about the same size. Place one grain in each tube of medium in tubes numbered 1 through 9. DO NOT PLACE A GRAIN OF YEAST IN TUBE NUMBER TEN. Hold the tube between your thumb and forefinger and strike the bottom of the tube with the fingers of your other hand. This should thoroughly mix the yeast into the medium. Your teacher can show you how to do this.

Keep all the test tubes at room temperature.

Today you are to count the number of yeast cells in test tube 1. Use the sampling method that you practiced the other day. Each team of four students will make two slides, one for each pair of students. In this way you can exchange slides and check on each other's accuracy.

You may find that you have too many cells to count accurately. Counting will be easier if you dilute your culture first. Take 1 ml of your culture and place it in a test tube containing 9 ml of distilled water. Mix the solution thoroughly and then make your count. Remember to multiply your count by 10, since you have diluted your culture by 10 (9 + 1 = 10).


1ml yeast culture
Yeast culture
9ml water

Place your results on table A, in the column headed Day 1.

If you have difficulty counting the yeast cells, you can make dilutions as you did before. You may need to repeat the process two or three times as shown in the diagram. Just remember to multiply your results by 10 for each dilution you make. Remember to stir your tubes before you take samples.

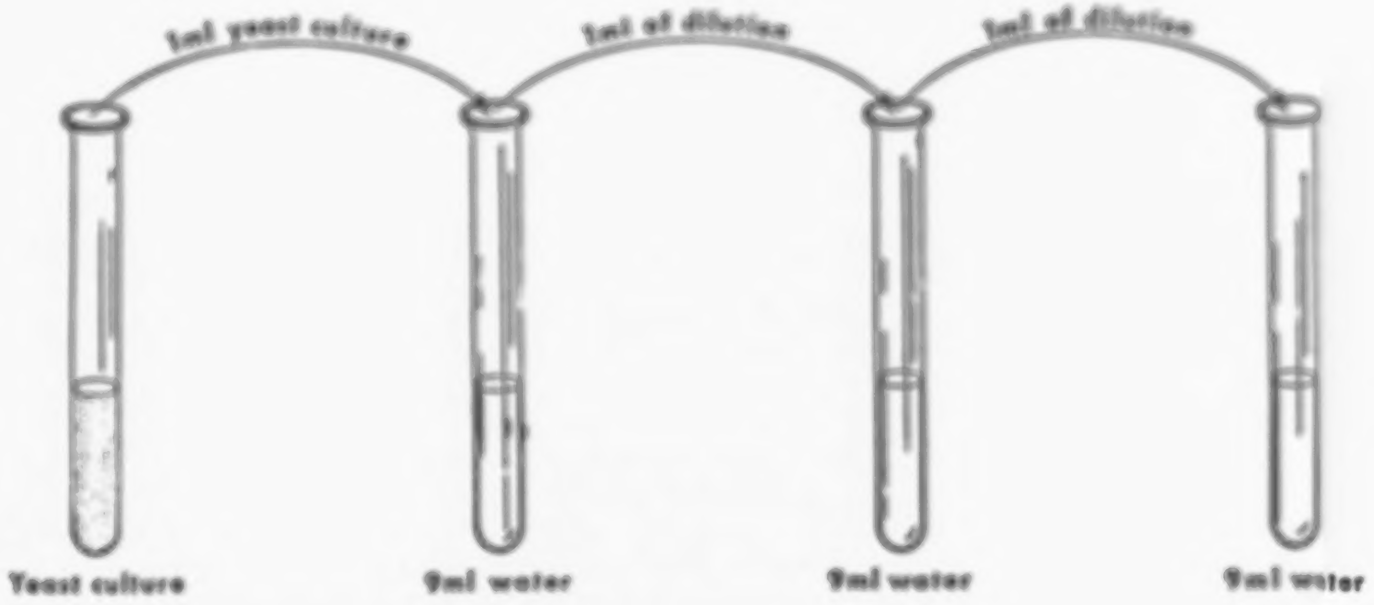

1ml yeast culture
1ml of dilution
1ml of dilution
Yeast culture
9ml water
9ml water
9ml water

TABLE A. CHANGES IN A YEAST POPULATION

Count	Day 1 Tube 1	Day 2 Tube 2	Day 3 Tube 3	Day 4 Tube 4	Day 5 Tube 5	Day 6 Tube 6	Day 7 Tube 7	Day 8 Tube 8	Day 9 Tube 9
First									
Second									
Third									
Fourth									
Fifth									
Average									

Counting days two through nine

You can continue the exercise for as many days as you have tubes containing medium and yeast cells. You should have a good picture of what has happened to the population after nine days. On day three use the culture tube numbered 3; on day four, use 4; etc. Record the data collected each day in the appropriate column of your table.

BACKGROUND

The students have previously developed the concept of random sampling as a means for counting a large population. However, in all cases the technique of random sampling has been applied to macroscopic populations such as man, dandelions or lizards. The students are then presented with the problem of deciding how to use random sampling to count a dense microscopic population. The discussion leading to the solution is an integral part of the total learning activity of laboratory work. The discussion takes the form of a dialogue between teacher and students. Teacher explanations are added only when there is need for clarification. After the students have solved this problem, they can begin laboratory investigation making use of the technique of random sampling.

*SUGGESTED TEACHER-PUPIL DIALOGUE OF THE CHANGE IN A YEAST POPULATION

On the first day of this activity, the students are presented with dense yeast cultures and instructed to make a microscopic slide using a drop of the culture. This gives the teacher an opportunity to check the technique of the preparation of wet slides. Each student is then asked to count all the yeast cells on his slides. It doesn't take long for one of the students to inform the teacher that the request is an impossible one.

Tch: Since we can't actually count the yeast cells, is there any other way we could find out how many cells are on your slides?

Std: The initial response will usually be, "No."

Tch: Let's see which one of you can start to solve the problem of how to count the yeast cells. Can anyone think of anything we have done earlier that might help? (Eventually one of the students will remember that they used random sampling to count dandelions in the school yard earlier in the year. If this is slow in coming, lead the students with questions.)

Std. Could we sample the yeast cells as we sampled the dandelions?

Tch: What does someone else think about that suggestion?

Std: How can we use random sampling? We took dandelion samples by throwing wire squares. You can't throw wire squares on a slide!

Tch: What about that? Anyone have a solution? (There usually is a long pause while the students mull over this problem.) The teacher can guide the process as follows:

Tch: Everyone examine your slides again. Move the slide around and think about what you see.

Std: Could we use the circle we see through the microscope as our sample?

Tch: What does someone think of that suggestion? (The student will generally agree after giving the suggestion some thought.)

Tch: Would you want to use the high or low power field for your sample.

Std: High!

Tch: Why?

Std: It is easier to see the yeast cells.

Std: There are fewer cells to count.

Tch: Why?

Std: The space you see is smaller.

Tch: All right, we have agreed to use our high power field as a sample to help us count the yeast cells. How many samples should we take?

Std: We took ten samples when we sampled the dandelions.

Tch: Should we take ten samples?

Std: Ten samples are too many, could we take five?

Tch: Why is it necessary to take five samples? Why wouldn't one do the same job?

Std: You might get the one sample from a spot where there were not many cells. If you sample five spots, you will get a better idea of the true number of cells on the slide.

Tch: Let's try our new technique. Everyone take five samples on your slides and then calculate the average number of cells per sample. (This gives the teacher a two-fold opportunity: (1) a chance to check student sampling techniques, and (2) a good time to review how to calculate averages.)

Tch: If we took five samples from your cultures tomorrow, do you think the average sample size would be the same as today?

Std: Is there anything for the yeast cells to eat?

Tch: No, the cells are in distilled water.

Std: I think the cells will starve overnight.

Tch: What would this do to the average sample size?

Std: It would be smaller.

Tch: Why?

Std: There are fewer cells in the culture, so the samples will be smaller.

Tch: What do you think we should do to the cultures to be sure we get a typical drop of culture on our slides?

Std: Stir or shake the tubes to get the yeast cells up off the bottom.

Tch: Now, let's bring our discussion points together. You have agreed that the average sample size tomorrow would be smaller than today's sample size. What are we assuming when we agree on this?

Std: The cells are going to starve tonight.

Tch: Right! What if we took five samples of the culture day after tomorrow?

Std: They would be even smaller.

Tch: If?

Std: If the yeast cell starves to death in the culture.

Tch: Why would the samples be smaller?

Std: The cell content of the tube decreased so the sample sizes would decrease.

Tch: What would we have found if, instead of dying, the yeast population had increased in our cultures?

Std: The sample size would have increased.

Tch: We have agreed that we can detect changes in the yeast population by sampling each day. Did we ever actually total the number of cells on the slide?

Std: No!

Tch: Do you think we need to perform this calculation to find out what is happening to the yeast?

Std: It might be more accurate if we did.
No, we can tell what's going on by sampling.

Tch: So far, we have just been guessing concerning what might happen to a yeast population. Let's use our new sampling technique to see what will actually happen if we raise yeast cells in class. From our earlier discussion, what do you think we will have to do to keep our yeast alive?

Std: We must put some kind of yeast food in with the cells.

(At this point the teacher may wish to try to have the students determine what the yeast might "eat". This is not necessary for the success of the laboratory work. If the students can realize that the yeast cells need food, this is sufficient. The students are now ready to be handed the laboratory exercise concerned with the study of yeast population.)

Tch: We now must prepare a mixture of yeast food and water. Scientists call such a mixture a medium.

(In preparing the yeast growth medium, the students have the opportunity to develop measuring skills and the use of the metric system. The development of laboratory skills continues as the students measure out the medium into test tubes and cap them with aluminum foil.)

Tch: What could we do to be sure there is nothing living in the tubes of "yeast food"?

(Students will suggest many ways to kill any living thing in the tubes. Sterilization is the desired method.)

(After sterilization, each team of students is given ten tubes of growth medium. They are instructed to place one grain of yeast in each of nine tubes. No yeast is placed in the tenth tube. This will be used to introduce the idea of a control in the exercise although no explanation is offered at this time.)

For the next nine days, the students will work on their own, taking samples from one of their nine tubes and tube ten on each day as instructed by their printed laboratory exercise. Since this work takes only part of each class period, the students will work on a self-study program on graphing. In this way they will learn how to put the data they collect in the laboratory into graphic form.

As the sampling proceeds, some students will find that the yeast populations have become so dense they are difficult to sample accurately. When this problem arises, the students are introduced to the technique of dilution.

At the end of nine sampling days, the students have collected data showing changes in their yeast populations. They are then ready to plot their data on a graph. While the data obtained are not always predictable, the usual graph will show an increase in the first few days followed by a decrease in the population in the last days of sampling. The teacher should be aware that many factors can and will affect the final graphs.

When plotting their graphs, the students will ask what to do with the data for tube ten. This is the time to introduce the idea of a control.

Tch: Tube ten was the tube in which we put growth medium but no yeast. This tube was to help us check something about our investigation. What do you think it checked?

(This discussion may be quite lengthy or very short depending on the class.)

Std: We checked to be sure we had killed all the living things in our tubes when we sterilized them.

Tch: Why do we need to know if we had killed all the living things in the tubes?

Std: Other things in the tubes might affect our results.

Tch: How?

Std: If they eat the yeast food, the yeast might starve.
They might eat the yeast.
The yeast might eat them.

Tch: What if some living yeast had gotten in our tubes before you added the yeast?

Std: There would have been more yeast in the tubes than we thought.

Tch: What would this do to our results? Our data?

Std: It would affect it in some ways.

Tch: You now see that tube ten helped us be sure that the only living things in our tubes was the yeast you added. Any changes in the yeast population will then be due to what happened to those cells. This check on our experiment is called a control. Look at your graphs. What do your graphs tell you about the changes in your yeast population?

Std: The number of yeast cells increased, then decreased.

Tch: What caused the decrease? (The student response here will be extremely varied. They can only guess as to the cause so the sky is the limit.)

Tch: Does our investigation prove which of these factors you have mentioned actually caused the decrease in your populations?

Std: No!

Tch: How could we prove that one of these factors was the cause of the population decrease?

(Here the students launch into possible procedures for solving this new problem and have a chance to work with experimental design. They begin to see that solution of one biological problem opens up many new questions.)

SUMMARY

In the work just discussed, the student has had an opportunity to develop and practice many skills.

1. Microscopic skills.
2. Measuring skills.
3. Graphing.
4. Sampling techniques.
5. Calculation of averages.

It is hoped that the students will begin to develop an understanding that:

1. The living organism is affected by its environment.
2. A scientific investigation is set up under controlled conditions.
3. Scientific investigation produces more questions.
4. Apparent failure in scientific work is not defeat but something from which a scientist gains information for future investigation.

* *Teacher-Pupil dialogue represents the experience of a committee member in an actual classroom activity.*

ADVANCED BIOLOGY
Grade Twelve

ADVANCED BIOLOGY

RATIONALE

Contemporary science is in a state of constant change. These changes have stimulated science educators to evaluate existing curricula. Recently developed curricula for introductory high school biology and other disciplines mandate re-examination of existing advanced biology courses. Curriculum materials specifically designed for the second year of high school biology are virtually nonexistent. Teachers have generally designed their own second year course patterned after their college experiences. Thus, there is a chance that advanced biology has evolved into a specialization course at the college level. With the trend toward the investigatory approach to subject matter at the secondary level and with indications that the collegiate level is following this trend, it is desirable to have a second year course which also reflects this trend. The aim of such a course would be to create positive attitudes toward science. This could be achieved through student participation in experiences which develop increased understanding not only of biology, but also of the scientific method.

Who – Student Identification and Selection

Many students in their senior year of high school are interested in the challenge afforded by individual investigation in science. They have developed skills in the various disciplines of science and mathematics which are applicable to interrelatedness and integration. A second year biology program developed on a theme of problem solving can best achieve interdisciplinary union of these separate skills. In many ways, biological science is best able to accomplish this desired goal as there is greater latitude for establishing investigatory situations with the types of classroom facilities available in most high schools. Also, the total background and training of biology teachers are frequently better oriented to guide advanced topic work with inter-discipline support. Biology teacher training at the collegiate level includes course work in the physical sciences and mathematics; the converse is rarely true. Thus, the broader preparation of this member of the teaching staff can be coupled with the need of those students desiring additional science experience.

Students who have professional, technical, and/or academic interest in the sciences would benefit by taking this course. Also, the non-science oriented student who desires broad understandings of science, as a way of life, should be encouraged to select this course. The prerequisites should include a year of biology and physical science (chemistry and/or physics) at the senior high school level, as well as two years of senior high school mathematics. **THE COURSE SHOULD NOT BE OFFERED AS A SUBSTITUTE FOR THOSE STUDENTS WHO HESITATE TO TAKE HIGH SCHOOL CHEMISTRY OR PHYSICS.**

COURSE GOALS

The program should afford rigorous academic experience through a lab-centered inquiry approach. This does not imply acquisition of many facts at the expense of understanding. Materials should not stress encyclopedic presentation of biological information. The topics covered should be limited to those that the instructor can handle in depth. Problem recognition, experimental design, collection of pertinent data, analysis of data, and formulation of hypothesis should be included. Each of these should be introduced within the framework of a problem under investigation. The problem, therefore, serves as a dual tool: to increase specific biological knowledge and to develop skills needed for investigation. Investigations should allow the student to achieve greater mastery of laboratory skills. The distinction and merit of data which are collected on an empirical basis as opposed to a hypothesis basis should be considered. For example, the routine testing of all kinds of chemicals for cancer control would be an empirical approach; whereas, testing only chemicals which influence cell division would be a hypothesis approach.

No investigation can be limited to merely laboratory work but needs to be supported by related literature, including journals. Controversy in science can then become apparent. In fact, controversy in science should be introduced by presenting some general area on which researchers disagree. Further, the conditional "truth" of scientific explanation will be better appreciated by students who are trained to test data by statistical methods. The role of statistics as a research tool should be used by the student. This can introduce students to the idea that there are different confidence levels in the interpretation of a set of data.

An awareness and concern for the multitude of major biological problems facing the world, such as pollution, overpopulation, nuclear fallout, and other current problems should be included so the student associates his more immediate experience with the related world problems. A text which approaches a second year biology curriculum with these goals in mind is **Interaction of Experiments and Ideas,** BSCS.

COURSE CONTENT

Recognizing that biology is a study of life, it would be wise for teachers to plan to keep the student constantly in contact with living things in the concrete, not in the abstract. One should strive to promote an attitude where "science" is thought of as a verb, "I science, you science, we science"; then students who are investigating in a laboratory will see the true purpose of science as a process not as a collection of facts.

The teacher's role is one of guiding, not leading the student's investigation. An overview of the teacher's role is given in an article entitled, "Experience and Experiment in Biology" by Paul Weise, Science, May 11, 1962; Vol. 136, No. 3515, page 468-471. This paper redefines the merit of investigation.

The previously mentioned text, The Interaction of Experiments and Ideas, is the only investigatory approach presently available. It is described in an article in "Journal of Research in Science Teaching," Vol. 2, page 60-64, 1964.

This book is neither a text nor a laboratory manual in the conventional sense. It does not present a compilation of factual information to the student, but rather pertinent biological topics for student investigation. These topics include: respiration, population dynamics, mechanisms of inheritance, growth patterns, developmental patterns, regulation of processes, and behavior of organisms.

LABORATORY GOALS

The majority of the students' time, 80% or more of class time, is to be spent conducting investigations to answer specific problems. The student uses the basic tools and techniques of research scientists. These include developing powers of observation in experimental situations, and recording and analyzing pertinent data. Statistical analysis of data illustrates the role of probability in making intelligent decisions. After the students have investigated specific topic areas, then they are ready to design an investigation to test a hypothesis suggested from the data. This fosters student independent study. The laboratory examples which follow, trace the evolutionary development of current explanations of plant hormone action.

*SAMPLE LABORATORY ACTIVITY

In order to stimulate hypothesis formation, the students are assigned to read an introductory section, in the text, related to plant growth. This section relates to man's recognition of multitudinous plant and animal species with their differences in adult form. This seems to indicate that the majority of organisms follow a given pattern during growth and development. The most highly organized animals follow a pattern of growth and development which results in a predictable size and shape. Such an unvarying mode of growth is referred to as determinate growth. Plants seldom have a final size and shape. Perennials grow additionally each year. This mode of growth is called indeterminate growth.

This section implants the idea that the internal environment of a plant system may be influenced by external factors such as light and temperature. This idea is then expanded to recalling the role of light in photosynthesis. Since some of the food produced by photosynthesis is used for the growth of the plant, could light possibly have additional roles? (Does it promote, inhibit, or have no effect upon the growth of a plant.)

At this point, the students are asked to suggest ways of determining which of the above three roles light plays. They readily suggest the needed variable. Which species would you suggest using? Normally the suggestion will be a plant species which they have used earlier in the year. Does light necessarily have to have the same effect on all plant species? This question produces considerable discussion. The students normally come up wtih evidence to support the idea that it is not unusual to have different species reacting differently. What kind of variations do you think the control and experimental groups will demonstrate? The light group is making food; therefore, it should be heavier and taller than the group grown in the absence of light. Invariably one student will suddenly remember that light is needed for chlorophyl production and suggest this as an expected variable. Usually some student will suggest that the roots may be affected but he should be reminded that roots always grow in the absence of light. "Would the difference in the environment of the stem affect the root?" This question normally produces much discussion but less decision as to what to expect. If you expect the stem to differ, would you expect the outgrowths of the stem to differ? Considerable discussion will follow and suggestions of variations in possibly number and expansion of leaves are usually forthcoming.

Depending upon the sophistication of the group, it is now possible to either refer them directly to a designed "lab" such as the one included at the back of this section, or continue through questions to develop the procedure. A group which has shown considerable skill and which enjoys procedural design should be given the opportunity to develop this procedure. The teacher's role is to be sure that they have considered and accounted for all factors. These factors include: seed variety, planting technique in relation to seed size, and length of time to run the investigation.

While the plants are growing, the students make decisions concerning techniques of obtaining the data and how to combine data from each group. The decisions, in part, rest on clear definitions of plant parts for linear measurements. In addition, the question of using a wet or dry mass has to be resolved on the basis of validity of the results.

After tabulation of the results, the following questions could be used for class discussion:

1. Does light have any effect on the growth of stems? If so, state what this effect seems to be.
2. Do plants, classed as monocotyledons, differ in their response from that of dicotyledons?
3. Are the leaves of plants grown under the different conditions similar in size?
4. Does light have any apparent effect on the formation of chlorophyl?
5. Are the differences significant?
6. Is the mass affected by the difference in environment?

The data will seem to be a contradiction to the expectations of the students. Reading assignments pertaining to the problem should be made; a good one is **The Power of Movement in Plants,** by Charles and Francis Darwin. Biological Science,* **Interaction of Experiments and Ideas,** p. 222. Perhaps the student could be referred to materials from his general biology course. Following this collection of new data, the students should re-examine the data from the "lab".

By this time the students have become reacquainted with plant hormones. A standard investigatory procedure in hormone studies is to assay for the presence and concentration of a specific hormone. If the students are not familiar with the concept of a "standard curve", the concept should be developed through a series of questions. Once this has been developed, the student may then proceed with a second investigation involving an assay. Outside reading should provide answers as to why the oat seed is being used and why it is imperative that the coleoptile is within a specific length range. The students would profit from reading simultaneously James Bonner's article, "Plant Hormones." This is in **Frontiers of Science** edited by Edward Hutchings, Jr., 1959, Basic Books, New York. Following the completion and discussion of the "lab", N.P. Kefford's article "Natural Plant Growth Regulators" could be assigned. This is in the December 13, 1963 issue of "Science." These two scientists have differing viewpoints concerning the mechanism of auxin action.

In order to assist the student in reading these technical articles, they should be encouraged to take notes. Following the reading of the articles, open-note quizzes should be given. A few sample quiz questions are given below:

Banner, J. : "Plant Hormones"

1. Evidence that auxins might, in an active complex, be bound to protein by peptide-like linkages involving auxin carboxyl group comes from:

   a. auxin release by proteolytic hydrolysis

   b. auxin synthesis by photolysis

   c. protein synthesis by hydrolysis

   d. none of the above

2. 2, 4-D is according to the theories presented in this article:

   a. an antiauxin

   b. a herbicide at low 10^{-8}M concentrations

   c. an auxin

   d. all of the above

3. Plant hormones are **not** active in establishing and maintaining which of the following plant functions:

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* *Biological Science:* **Interaction of Experiments and Ideas,** *Prentice-Hall*

a. integration of organs and tissues

b. control of growth

c. synchronization of plant activities

d. none of the above

Kefford, N.P. : "Natural Plant Growth Regulators"

1. With the identity of native auxin being determined as IAA, the pressing problems of auxin growth-regulator research will involve:

   a. studies of enzymatic indole chemical artifacts

   b. synthesis, movement, metabolism and regulation of auxin concentration in particular cells

   c. biological assay of the supramacrogram quantities of indole compounds

   d. GAA, IBA, and conjugated precursors

2. Study of growth-regulatory compounds is difficult and in most cases the controlling activity can be defined only:

   a. on the basis of diffusion pressure deficit

   b. in relation to the mole weight of the specific compound

   c. in terms of a specific biological assay

   d. after hydrolysis and creation of artifacts

3. The main factors in coconut milk which stimulate cell division and growth in excised phloem tissue of carrot root are:

   a. florigen, gibberellin, IAA-oxidase and milchin

   b. ribonuclease, oxidase-DNA, cytokinesis and exudate

   c. auxin, kinin, hexitols and reduced nitrogen compounds

   d. rootenone, phloemidase, milchin, and nicotinamide

FORMAL WRITE UP FOR THE TWO LABS DISCUSSED

As a result of these two laboratory investigations, the student's reading, and class discussions; the students will have a large number of problems to which they would like answers. They should be given the opportunity to investigate some of these. This can be approached through investigations which can be found in texts and/or through student design.

INVESTIGATION 30: The Effect of Light on the Growth of Seedlings
(page 221, **Biological Science: Interaction of Experiments and Ideas)**

MATERIALS (per team)

1. Germination trays

2. Seeds of Alaska peas

PROCEDURE

1. Each team should place about forty Alaska peas in each of two germination trays containing sand or vermiculite.

2. Water the sand or vermiculite well, but drain off excess water. Place one tray in the dark and leave the other tray in the room exposed to light.

3. After seven to nine days examine all of the plants and make detailed observations and measurements which might provide information to help you evaluate your hypothesis. Record this data in your notebook.

INVESTIGATION 31: The Biological Assay
(page 227, **Biological Science: Interaction of Experiments and Ideas)**

MATERIALS

1. Several hundred grains of oats, **Avena sativa,** variety Victory
2. Germination box equipped with red clelp
1. Several hundred grains of oats, **Avena sativa,** variety Victory
2. Germination box equipped with red cellophane and light shield
3. Indoleacetic acid
4. Sucrose
5. Cutter for cutting uniform sections of coleoptiles
6. Six petri plates per team
7. Milimeter rulers
8. One 10 ml pipette per team

PROCEDURE

1. Each team should count out 50 grains of oats.

2. Divide the grains equally among the team members and remove the husks. Husking is a somewhat tedious operation, but it may be made easier if the grains are placed on a piece of paper towel and rolled with the palm of the hand. Label the grains (class, team, experiment, date) and store at room temperature until the next class day.

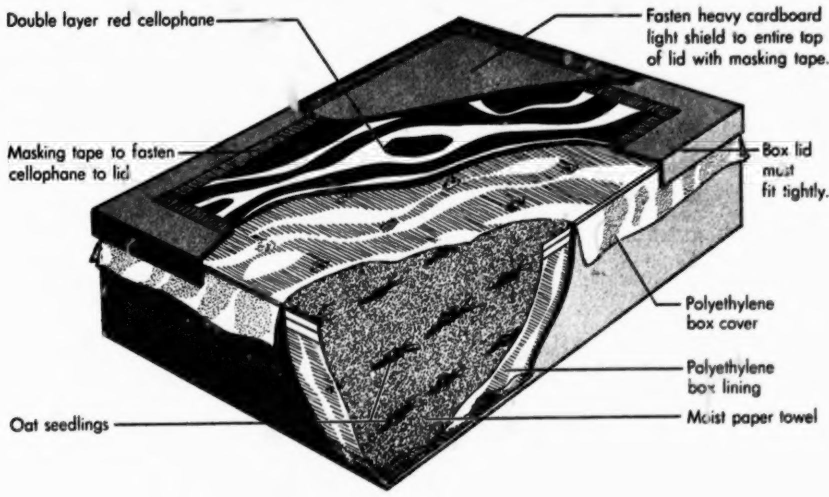
3. Before placing the husked grains in the germination box, soak them for not less than two hours and not more than four hours.

4. Place the husked grains in uniform rows on several layers of moist paper towels in a germination box. Cover the box with a sheet of clear polyethylene and then cover the box with the lid with the red filter and light shield as shown in Figure 61. Be sure the lid fits snugly and that the light shield over the top allows no light to enter even through the red cellophane.

   Leave at room temperature for 24 hours.

5. After 24 hours, remove the light shield (not the box top). Allow light to pass through the red cellophane for a period of thirty minutes. Replace the light shield on the box cover.

Germination box with red filter and light-proof shield.


Double layer red cellophane
Fasten heavy cardboard light shield to entire top of lid with masking tape.
Masking tape to fasten cellophane to lid
Box lid must fit tightly.
Polyethylene box cover
Polyethylene box lining
Oat seedlings
Moist paper towel

6. Immediately after the thirty-minute exposure, darken the room as much as possible. (Ideally you should work in a dark room with only a red light, but if you work rapidly with low light intensity the experiment should be successful.) Working quickly, remove the box cover and the polyethylene cover and carefully add previously moistened vermiculite to a depth of ½ inch over the germinating grains in the germination box. Gently pack the vermiculite to a uniform level and immediately replace the polyethylene cover and the box cover with its light-tight shield. Leave the germination box at room temperature for two to three days without opening it.

7. Stock solutions of 4% sucrose and various concentrations of IAA should be prepared. A stock solution containing 100mg of indoleacetic acid per liter may be prepared as follows: Dissolve 100mg of IAA in 1 to 2 ml of alcohol and add this to about 900 ml of distilled water. Warm this mixture gently on a hot plate or steam bath to drive off the alcohol. Then make up to one liter with distilled water.

   Solutions containing 20.0, 2.0, 0.2, and 0.02 mg of IAA per liter can be prepared by serial diluting this stock solution.

   These dilutions should be prepared shortly before using, because IAA is not very stable. The stock solution may be kept for one or two weeks if refrigerated in a dark bottle. Prepare enough of each dilution for all teams. (Each team will use 10 ml of each.) The instructor will provide a solution of IAA, the concentration of which will be unknown to the student.

8. On the day that the seedlings will be ready, each team will prepare six clean petri plates. After labeling each dish, add solutions to each as follows:

TABLE 18: Preparation of Petri Plates for IAA Assay

Dish No.	Add
1	10 ml water + 10 ml 4% sucrose solution
2	10 ml 0.02 mg/1 IAA stock solution + 10 ml 4% sucrose solution
3	10 ml 0.2 mg/1 IAA stock solution + 10 ml 4% sucrose solution
4	10 ml 2.0 mg/1 IAA stock solution + 10 ml 4% sucrose solution
5	10 ml 20.0 mg/1 IAA stock solution + 10 ml 4% sucrose solution
6	10 ml unknown + 10 ml 4% sucrose solution

   Calculate the final concentration of IAA and sucrose in all dishes.

9. Approximately two to three days after covering the germinating grains with vermiculite, darken the room as much as possible and remove the germination box cover and polyethylene cover. Select thirty seedlings with straight coleoptiles from 1.5 to 2.5 cm in total length.

10. Cut off and discard the root and remaining part of the seedling and carefully line up the coleoptiles, two or three at a time, on a block of paraffin. Using the special cutter, cut from each coleoptile a 10 mm section back of a 3 mm tip and place five of the 10 mm sections in each of the petri plates previously prepared. Store them in the dark for 24 hours at a temperature as near 25°C as possible.

11. At the end of the 24 hours, remove the coleoptile sections from the dishes and measure their lengths to the nearest 0.5 mm. Record the results in a chart similar to Chart D page 60.

QUESTIONS FOR DISCUSSION

1. Plot your data on a graph with increments of growth on the vertical axis and concentration of IAA on the horizontal axis.

2. Compare the results of your team with those of other teams in your class, and if possible with those of other classes.

3. Compute the mean increase in length of the coleoptiles in each dish. Are the data continuous or discrete?

4. Using the proper test, determine if the means in each dish with IAA are significantly different from each other and from that of the controls.

CHART D. Effect of IAA on Coleoptile Elongation

		DISH-CONCENTRATION (mg/1)					
		1 0	2 0.01	3 0.1	4 1.0	5 10.0	6 unknown
Coleoptile Sections	1						
	2						
	3						
	4						
	5						
Average length:							
Initial length:							
Average change in length:							

5. What is the concentration of your unknown solution?

6. Explain the mechanism of phototropism and geotropism.

APPENDIX

APPENDIX

SUGGESTED GUIDELINES FOR THE EVALUATION AND SELECTION OF A LAB-TEXTBOOK

Having decided **HOW** you wish to teach biology and **WHAT** you wish to teach, the next step is probably the evaluation and selection of a textbook. It is obvious that the text should support, not dictate the curriculum.

The term lab-textbook was selected to indicate the importance of the laboratory work in this kind of a curriculum. **It has been hypothesized that as often as practical, new skills, ideas, and/or concepts are met by the students first in the laboratory then amplified by textual readings.** The laboratory work is the essence but not the sole learning experience. A well-written text can give added meaning to the laboratory investigations. Ideally, the laboratory guide and the text would be a cohesive unit.

HOW TO USE THE GUIDELINES

This suggested criteria consists of seven questions which, if carefully considered, will aid you in text analysis. Statements which accompany each question will direct you to specific aspects of the text. Answers to the questions may be gotten through examination of: the table of contents, the preface, the body of the text, the appendices, etc.

I. ARE LABORATORY INVESTIGATIONS AN INHERENT PART OF THE PRESENTATION OF TEXTUAL MATERIALS?

MAKE SURE THAT:

1. The laboratory experiences assist the students in the development of inquiry skills.
2. The textbook presentation becomes the logical outgrowth of the laboratory experience.
3. The approach of the text is in accord with the investigative nature of the laboratory. The laboratory instructions may be an integral part of the text, a separate manual or teacher generated.

II. IS THE TEXT BASED ON CURRENT PHILOSOPHY? (This is particularly important if the text is a revised edition.)

MAKE SURE THAT:

1. The author's statement of philosophy is based on student-centered investigation.

2. The copyright date and materials indicate recent issuance (this should not exceed five years).

3. This edition is not largely the previous edition without serious revision.

III. ARE THE AUTHORS QUALIFIED?

MAKE SURE THAT:

1. They have adequate preparation as indicated by their degrees and past experiences.

2. They have had experience at the level for which they are writing or at least have had assistance from consultants at that level.

3. They have had help from additional qualified personnel.

IV. DOES THE TEXT STRESS THE INTERRELATIONSHIPS OF BIOLOGICAL CONCEPTS?

MAKE SURE THAT:

1. The units or blocks of content interlock and indicate relatedness.

2. The interdependence among major themes is clearly apparent to students.

V. IS THE "FACTUAL" INFORMATION PRESENTED ACCURATELY AND IMPARTIALLY AS A PRODUCT OF SCIENTIFIC DISCOVERY?

MAKE SURE THAT:

1. The development of "factual" information is set within an historical framework. Case studies, when used, should illustrate that such information is the result of scientific inquiry.

2. There are clear statements which indicate that current knowledge is based on the observations recorded and verified by many workers over a long period of time.

3. The concepts are presented with the attitude that modifications or corrections may be necessary as additional information is accumulated and analyzed.

4. There are clear statements which illustrate that our knowledge develops as the result of the extension of our senses via instruments.

5. The author is not guilty of loose or careless thinking in the wording of technical statements.

6. Technical terms are readily observable so that the student preceives the importance of explicit meanings as a tool of science.

VI. TO WHAT EXTENT ARE THERE GRAPHS, TABLES, OR CHARTS WHICH PROVIDE AN INVITATION AND OPPORTUNITY FOR THE STUDENT TO INTERPRET DATA?

MAKE SURE THAT:

1. Text presentation progressively requires more student interpretation of data.
2. The illustrations serve as an extension and/or supplement to the text.
3. There are regular and pertinent textual references to the illustrations which are adequately labeled.
4. The idea or concept involved in each graph or illustration is readily apparent.

V. DO THE EXERCISES ENCOURAGE THE STUDENT TO BECOME INVOLVED IN FURTHER INQUIRY?

MAKE SURE THAT:

1. Exercises assist the student to develop an ability to hypothesize, analyze data, and make generalizations.
2. Suggestions for further investigations are stated and/or implied by the textual material. These suggestions may be in the body of the text or in special sections.
3. Reading lists are graduated in difficulty as to provide challenging material for all students.
4. Suggested reading materials which are readily available are listed.

LABORATORY PHYSICAL STRUCTURE

RATIONALE FOR LABORATORY PHYSICAL STRUCTURE

In a biology course planned around the concept of "scientific inquiry," the student should be engaged in a variety of scientific investigations. If this is done, the teaching facilities must be supportive to the learner. This implies that a combination classroom-laboratory room is most suitable. Because of the "space" requirement it is not feasible to share laboratory room facilities within a department. It is also not prudent to consider team-teaching because of the non-flexibility of scheduling. Living things do not wait until the student is in the laboratory the next time. Science is a "personal" experience and space, facilities, and time must be provided to insure that it is. As a result, the student will become involved with many biological experiments requiring several days and maybe even weeks to complete. The biology room therefore must have ample work space to set up and continue numerous experiments.

Because of the diversity of equipment and materials needed for learning biology, the development of good teaching facilities for biology is somewhat more complex than for chemistry or physics. Each "group" of needed living plants and animals requires a different set of survival conditions. Different kinds of plants, aquatic and terrestial organisms, and microscopic organisms all require different environmental maintenance conditions. There is need of constant and varied temperatures, light, humidity, and ventilation. This also increases the space requirements since living organisms require time to grow. The storage of multi-types of equipment and materials increases the need for space also.

In designing new buildings or remodeling existing facilities, the architect and administrator should consult the classroom teacher. Since the life expectancy of the majority of schools constructed today will probably exist through several curricular changes, there is a need for flexibility as well as ease of remodeling to be considered.

The facilities, be they remodeled or new, which are suggested in the following sections are considered to be supportive to a vital and vigorous biology curriculum. It is no longer enough to provide a room with tables, an aquarium, and a sink and feel confident that a course worthy of current educational philosophy could succeed without sacrifice of its very soul. There is no need to apologize for the goals that are set, for are we not dedicated to giving our ultimate to achieve youth's ultimate? The "youth's ultimate" becomes whittled downward as the facilities are whittled. Fortunately, most of the original expenditure is for permanent installations which have a longevity that warrants such expenditure. The facilities suggested **are not the maximum** but more nearly approach the minimum.

JUNIOR HIGH LIFE SCIENCE LABORATORY FACILITIES

STUDENT NEEDS

Junior high students are active and busy, thus room must be allowed for freedom of movement to and from various work areas in the room. Each student will be involved in "doing" as they investigate problems. To promote the process of scientific investigation, each pair of students needs a work area equaling a table surface area of 20" x 36" with acid resistant table tops. Each group of two to five students will need a heat source such as gas outlets for bunsen burners or a hot plate, 110-volt grounded outlets, a 14" x 8" acid resistant sink with a rigid gooseneck water spout. This is ideal, but two to four clean-up areas so equipped will be adequate; however, two student tables may allow for more flexibility. Alcohol lamps may actually be better to use than having gas outlets for bunsen burners. Rolls of asbestos cloth may be used to make older tables heat and acid-proof until better science furniture is available.

ROOM AREA NEEDS

The junior high school laboratory should contain the following: 1) student work areas, 2) a "living" area for animals and plants, 3) a clean-up area, 4) an equipment storage area.

The student work area needs have been discussed above, but many take various forms as illustrated by drawings at the end of this section. The "living" area should provide adequate space for growth of plants with 110-volt outlets to operate lights. Space is required for animal care and cages. Ventilation is essential to remove odors from the room. This area need not be large and a counter at the rear of the classroom could be used. Open shelves and counter space is needed for continuing student experiments. These shelves should be at least 18" deep and have 110-volt outlets available.

Book shelves should include display and storage for periodicals and reference books. A conference and reading table would be an excellent addition for small group work and reading. The clean-up areas need hot and cold water, large sinks with drain boards, glassware drying racks (peg boards) and cleaning compound dispensers. This area should be provided for each set of 8 to 10 students. The equipment storage area should consist of cabinets with doors. Tote tray cabinets are very useable for some types of storage. Open shelving is needed for large items and should have a depth of 18" with adjustable shelves. Bulletin boards are needed around the room in some areas and a minimum of two sections of blackboard.

It is felt that the equipment in the junior high laboratory should not be as elaborate or as sophisticated as the tenth grade laboratory room.

The equipment should be simple, not expensive and the teacher should make every effort to use "things" available from the local hardware and other local businesses. For example, disposable aluminum pans, aluminum foil and milk cartons may be used in many ways and will substitute for many types of laboratory glassware. The teacher should encourage the student to build and use materials that are about them. The student at this level is not ready to handle elaborate equipment as found in many tenth grade laboratories.

SENIOR HIGH BIOLOGY LABORATORY FACILITIES

The biology laboratory-classroom needs to be located on the first floor with a direct exit to the outside if at all possible. The actual arrangement of areas can be achieved in several tried ways: perimeter, island bench, or pattened bench dispersal. Plans for various arrangements of areas are in the back of this section. The basic facilities can be grouped as follows: (I) the room must contain, or have access to 1) a library area, 2) an equipment storage area, 3) life areas, 4) preparation area; (II) each room must contain 1) student stations, 2) student experiment storage area, 3) student discussion-study area, 4) clean-up area, 5) space to allow for traffic flow, and 6) standard permanent equipment.

Considering Section I. Most of the four basic areas could be shared by a pair of teachers and housed within a connecting room. The life areas and possibly the preparation area could be shared by a total biology department.

(1) LIBRARY AREA

Scheduling is such that students do not have adequate time to visit the school library to hunt specific books. Also, the problem of "sharing" a limited number of books becomes a problem when they are housed in the library exclusively. These problems can be overcome by having a reference area in the room where students have access to them daily and so that they can be referred to during discussions. This area needs shelving (open is suitable) as well as a file cabinet to house reprints and pamphlets. Most of these books should be permanent members of the room library; however, books from the school library could be borrowed as they are needed. A study table would be a fine addition to the area.

(2) EQUIPMENT STORAGE AREA

There is a great variety of equipment, each requiring storage specialization. Chemicals, reagents, microscopes, models, glassware, display items, charts, cages, herbarium supplies, plant growth supplies, etc. Naturally, a variety of items requires a variety of storage methods. Generally speaking, closed nontransportable shelving is best. The shelving should allow achievement of varied distances between the shelves. The width of shelves should probably allow three sizes: 10", 18", and 28". Tote tray cabinets are ideal for small items of little weight and which are frequently transported. Record cabinets for storage of departmental work is essential also.

(3) LIFE AREAS

There are essentially four types of areas needed: (1) micro-organisms, (2) small macro-organisms, (3) animals, terrestrial and aquatic, (4) plants in varied habitats. These areas need temperature, light, humidity, and ventilation controls as well as specialized containers and supportive equipment. Sanitation and cleaning facilities must be considered as well as the time needed by the personnel to keep them operatable. In designing these areas for your specific needs, money can be saved by consulting two groups of persons: those persons who have devoted much of their lives to such specialized work such as the florist, a college professor who has worked in a specific area, etc., and those people who earn their living supplying such facilities. These areas are so specialized that any listing of items is too general to be worthwhile. Much consideration must be given to adequate environmental controls, maintenance of the areas in terms of personnel time and clean-up facilities. Consideration must also be given to the size of the facility in relation to the number of students and teachers who will use it.

(4) PREPARATION AREA

There needs to be provided an area well equipped with facilities for preparing the variety of solutions and media used in biology. Gas outlets or hot plates for a heat source, 110-volt, hot and cold water, acid resistant plumbing, a garbage disposal unit and fume hood are needed. A kitchen stove with a thermostat may serve as both a heat source and a sterilizing oven. Also, the area should supply a workbench section for minor repair to equipment and construction of some equipment. Facilities for obtaining distilled water could also be located here. A section for teacher, clerical and reference work would be a most desirable addition to this section.

Considering Section II. These six basic areas would need to be present in each laboratory classroom.

(1) STUDENT STATION

The student stations should be grouped to allow squads (4-6 in number) or paired student work. Work area should allow 20" x 36" per pair. A water source and sink, heat source, and 110-volt electrical outlet is needed for each student squad. (Acid resistant table top finish is needed.)

(2) STUDENT EXPERIMENT STORAGE AREA

Adequate space for storage of continuing projects is needed. Open shelving with variable distances between shelves and a width of at least 18" is needed. The amount and type which is needed varies with facilities for the development. If plant growth experiments are being conducted and no greenhouse available, a proper facilitated makeshift area must be developed. There are temperature-controlled experiments which also need proper area considerations.

(3) STUDENT-DISCUSSION AREA

The ability to rearrange the chairs (or chairs with attached writing arms) is vital to the type of group activity desired. To achieve more student participation, the teacher must seek their level and become one of them. This is best achieved through seating arrangements being variable. This arrangement should be assembled in the area of the blackboard, the bulletin board, the overhead projector, and a permanently installed screen. It must be an area which can be darkened adequately for use of the microprojector.

(4) CLEAN-UP AREA

Large sinks with acid resistant plumbing, sand traps, and garbage disposal are needed. Racks for drying of glassware and various types of cleaning compounds should also be in the area. Efficient utilization of this area precludes that there should be a clean-up area for every 6 to 8 students.

(5) SPACE FOR TRAFFIC FLOW

In designing the location of each area, thought must be given to traffic flow through and to and from each area. Educational time is costly and should not be wasted daily by clogging of traffic.

(6) STANDARD PERMANENT EQUIPMENT

Each room should house the following items for their individual use: stove with thermostatic controlled oven; autoclave or pressure cooker; one or two incubators; refrigerator, with freezer; projection screen and overhead projector; carts for transporting equipment; compound microscopes, (one per two students); dissecting scopes, (one per two students with adequate and proper storage); two balances for weighing very small quantities; and a blender. Many other items will be added as the department develops. Depending on how well equipped and provided the department is in terms of life areas, preparation area, and storage area, each room's needs will vary. Aquaria and terraria are needed; however, these need not and should not be large and permanently-installed. Plant growth areas and animal care areas are needed and should be temperature controlled and ventilated. Several equipment suppliers now have self-contained animal care cases and simple plant growth chambers designed for high school use.

One goal for which each school should strive is to make the school grounds a "living laboratory." The planting of trees and herb specimens should be planned with an eye for greatest variety possible as well as esthetic value. If possible, securing a local area with varied habitats which could be maintained in a natural condition is ideal.

SUGGESTED DRAWINGS OF FACILITIES ARRANGEMENT

The following drawings of facilities were obtained by permission from BSCS NEWSLETTER Number 9.[1] Depending upon individual situations, type of construction, or the remodeling program, will determine in part the arrangements within the room or rooms. While these suggested arrangements would be ideal in junior high school, these are not necessarily recommended.

Plan A:

Dual-purpose laboratory tables should be arranged in the center of the room and equipped with electrical outlets. These serve either as laboratory work-benches or as writing desks. Sinks are placed about the periphery of the room as part of a complete counter system, with both upper and lower wall cabinets. This provides space for additional work and storage and can be done in a room 30 x 35 feet. (See Figure 1.)

Plan B:

"U" shaped work areas arranged about the periphery of the room. Writing desks are then arranged in the center and are movable to facilitate lectures and discussions. This plan requires a larger room than the one listed above, i.e., a space of at least 30 x 45 feet. (See Figure 2.)

Plan C:

Island laboratory benches arranged throughout a room of 30 x 25 feet. Lectures are given in separate rooms. (See Figure 3.)

Plan D:

Island laboratory benches arranged at rear of a room 30 x 50 feet. Lecture and discussion seating at front. (See Figure 4.)

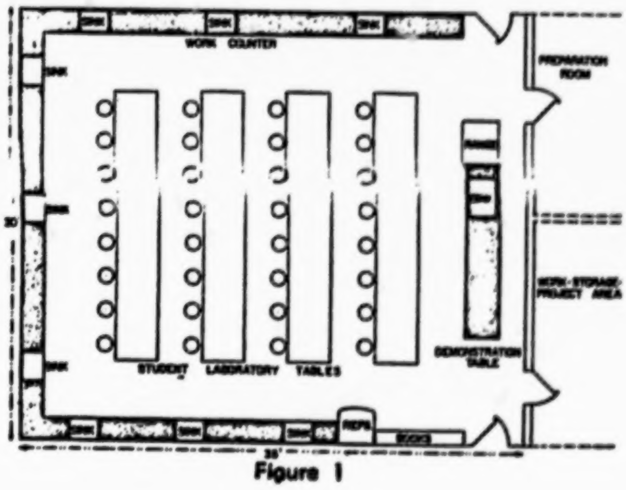

SINK
WORK COUNTER
PREPARATION ROOM
SINK
30
WORK-STORAGE-PROJECT AREA
DEMONSTRATION TABLE
SINK
STUDENT LABORATORY TABLES
30'

Figure 1

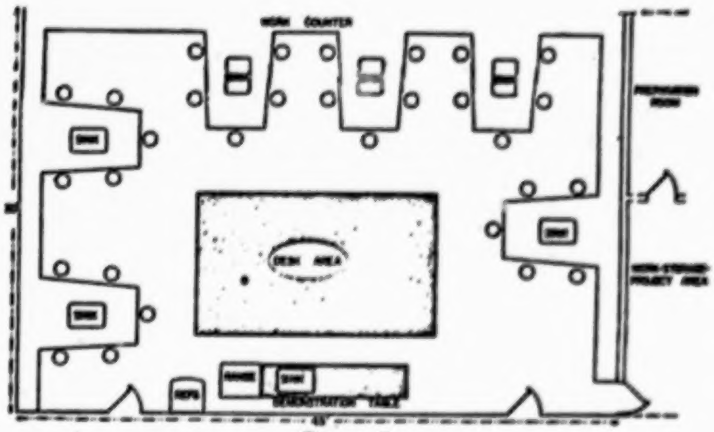

WORK COUNTER
PREPARATION ROOM
DESK AREA
WORK-STORAGE-PROJECT AREA
DEMONSTRATION TABLE
45'

Figure 2

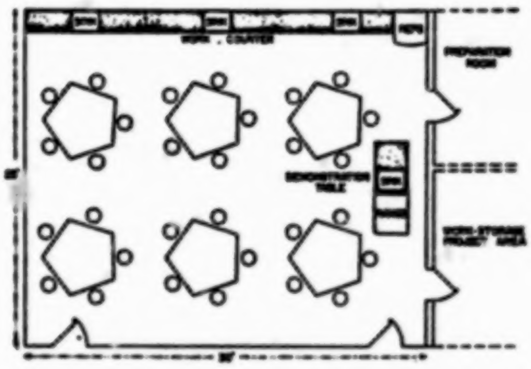

WORK COUNTER
PREPARATION ROOM
DEMONSTRATION TABLE
WORK-STORAGE PROJECT AREA

Figure 3

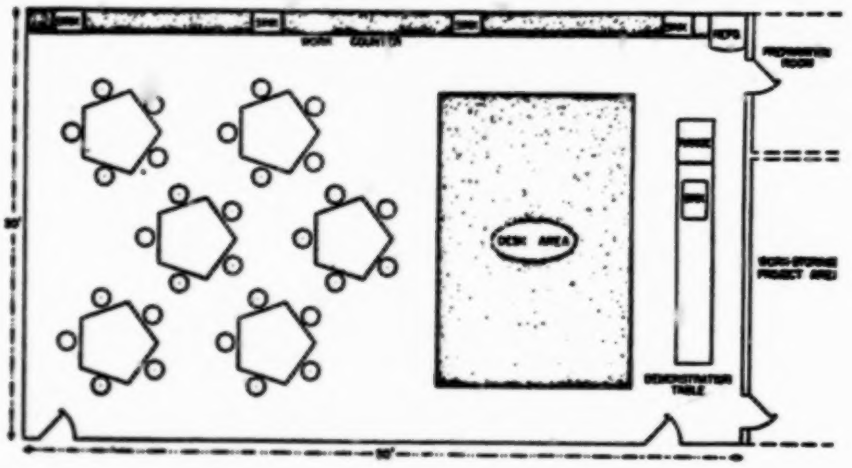

WORK COUNTER
PREPARATION ROOM
DESK AREA
WORK-STORAGE PROJECT AREA
DEMONSTRATION TABLE

Figure 4

EVALUATION OF LABORATORY FACILITIES

The following evaluation of laboratory facilities was obtained by permission from BSCS and was revised in the BSCS NEWSLETTER Number 25.[2] This guide is included to give you a method whereby you may evaluate your present laboratory and the one under design.

The check list in Table I, may be used in the following manner:

- For each facility listed, *circle* the category that best describes your laboratory. In the last column on that line, write in the point value for the circled item; i.e. the point value at the head of the column in which the circled item appears. E.g. under Fixed Laboratory Installations, if you have 200 square feet of shelf storage space, circle 200, and in the column at the extreme right put down 8 points, the value assigned to that item.
- Where the laboratory has none of the facility mentioned (i.e. where a dash is circled on the table) the response value is zero.
- Find the area sub-total for your school in each of the seven areas and compare it with the maximum possible score for that area.
- Obtain a grand total for all areas and compare it with the rating scale below:

RATING SCALE

Rating	* Points	Per Cent of Optimal
A	330-388	85-100%
B	273-329	70-84
C	215-272	55-69
D	155-214	40-54
E	97-154	25-39
F	0-96	0-24

REFERENCES

[1] BSCS NEWSLETTER Number 9.
[2] BSCS NEWSLETTER Number 25

LABORATORY PHYSICAL STRUCTURE

1965 Revised Laboratory Facilities Checklist

(Based on 28 students)

Facility	Point Value					
Category A	**16 pts**	**12 pts**	**8 pts**	**4 pts**	**Your School**	
1. Fixed laboratory installations—*maximum possible score 216 pts*						
Demonstration table	1	—	—	—	______	
Work counter (peripheral)—linear ft	120	60	30	15	______	
Sinks—regular	4	3	2	1	______	
—laundry	—	—	2	1	______	
Water—cold	4 taps	3 taps	2 taps	1 tap	______	
—hot	—	—	2 taps	1 tap	______	
Outlets—gas	7	5	3	2	______	
—electrical	7	5	3	2	______	
Compressed air	—	—	—	yes	______	
Garbage disposal	—	—	—	yes	______	
Shelf storage sq ft	450	300	200	100	______	
Preparation room	large	medium	small	—	______	
Life alcove	large	medium	small	—	______	
Project work area	large	medium	small	—	______	
Science library/min 50 vols	large	medium	small	—	______	
Display cases (in halls)	—	—	2	1	______	
Light and ventilation	good	fair	poor	—	______	
Sub-total points						______
2. Budget considerations—*maximum possible score 48 pts*						
Funds for perishables, glassware, chemicals, specimens, etc.	$500/yr	$250/yr	$125/yr	$50/yr	______	
Funds available *during* year as needed	yes	—	—	—	______	
Capital outlay funds	$500/yr	$250/yr	$125/yr	$50/yr	______	
Sub-total points						______
3. Microscopes—*maximum possible score 32 pts*						
Compound microscopes	28	14	7	4	______	
Binocular stereomicroscopes	28	14	7	4	______	
Sub-total points						______
4. Lab assistants—*maximum possible score 16 pts*						
Paid lab assistants—5 hrs per week per section	1	—	—	—	______	
Sub-total points						______
Category B	**12 pts**	**9 pts**	**6 pts**	**3 pts**	**Your School**	
5. Major equipment—*maximum possible score 111 pts*						
Refrigerator	1	—	—	—	______	
Gas range/oven	1	—	—	—	______	
Incubator	2	1	—	—	______	
Balances (.01 g)	4	3	2	1	______	
Autoclave	1	—	—	—	______	
Pressure cooker	2	1	—	—	______	
Centrifuge	—	—	2	1	______	
Temp, humidity, and light controlled chamber	—	—	1	—	______	
Fume hood	—	1	—	—	______	
Laboratory cart	2	1	—	—	______	
Power supply units (AC/DC portable)	—	—	2	1	______	
Sub-total points						______
Category C	**8 pts**	**6 pts**	**4 pts**	**2 pts**	**Your School**	
6. Small equipment—*maximum possible score 70 pts*						
Basic laboratory equipment*	many	adeq.	few	sparse	______	
Aquaria	4	3	2	1	______	
Terraria	4	3	2	1	______	
Glassware	many	adeq.	few	sparse	______	
Collecting equipment	many	adeq.	few	sparse	______	
Animal cages	8	6	4	2	______	
Covered disposal containers	2	1	—	—	______	
Electric hot plates	—	2	1	—	______	
Chemicals	many	adeq	few	sparse	______	
Sub-total points						______
7. Demonstration aids—*maximum possible score 48 pts*						
Specimen sets	many	adeq.	few	sparse	______	
Models and charts	many	adeq.	few	sparse	______	
Prepared microscope slides	many	adeq.	few	sparse	______	
Overhead projector	—	1	—	—	______	
Cartridge projector	1	—	—	—	______	
Slide projector	—	1	—	—	______	
Microprojector	—	—	1	—	______	
Sub-total points						______
All facilities—*maximum possible score 541 pts*						
Your school—total score						______

*Includes such items as centigrade thermometers, pipettes, gas burners, dissecting sets, tripod stands, ring stands, etc.

SUGGESTED LIST OF MINIMUM EQUIPMENT AND SUPPLIES

*It is not feasible to list in detail all items or the quantity of each item needed to support an investigatory course in biology. However, there is need to give some suggestion as to the types of supplies and equipment needed in order to teach such a course. All modern text-lab manuals give very detailed lists and the quantity needed for a specific class size. If there is a need to purchase the materials over a period of years, then the teacher should select those laboratory experiences which will be most beneficial to his students and purchase these materials first. There are teacher reference books† which direct one to make many of the needed items.

To obtain some idea of the quantity of major items, refer to the check list in the preceeding section.

EQUIPMENT

- Autoclave, (pressure cooker, 16 qt.)
- Aquaria and accessories
- Balances, 0.01 gm sensitivity
- Brush, test tube and beaker
- Bunsen burners, or alcohol lamps
- Cart, on wheels
- Corks, assorted sizes
- Dissecting sets, student
- Files, triangle
- Lenses, hand
- Metric sticks
- Microscope, compound stereo
- Nets, insect
- Refrigerator
- Ring stand, accessories
- Rubber stoppers, assorted solid
  - assorted 1 hole
  - assorted 2 hole
- Rubber tubing
- Sponges
- Stove, or hot plates
- Test tubes,
  - assorted accessories
- Thermometers, 10°C to 110°C
- Thermostat
- Trays, dissecting, tote
- Wing tops for Bunsen burner
- Wire gauze with asbestos center

Need assorted tools such as pliers, wire cutters, hammer, screwdriver, etc.

GLASSWARE

- Beakers
  - 125 ml, 250 ml, 500 ml, 1000 ml
- Bottles, dropping
  - wide mouth
  - assorted sizes
- Cover glass, #2 square
- Dish, Petri
  - stacking
  - Syracuse watch
- Flasks, Erlenmeyer,
  - 125 ml, 250 ml, 200 ml, 1000 ml
- Funnels, 8 cm diameter
- Graduated cylinders,
  - 25 ml, 100 ml, 1000 ml
- Pipettes, medicine droppers
  - 1 ml, 0.1 ml graduation
  - 10 ml, 1 ml graduation
- Rods, glass
- Slides, microscopic plain
  - microscopic concave
- Test tubes
- Tubing, glass, assorted diameter

CHEMICALS

- Acetic acid
- Acetone
- Agar
- Alcohol, ethyl 95%
- Beef extract
- Benedicts solution
- Bromothymol blue
- Carbon tetrachloride
- Carmine
- Dialysis tubing
- Distilled water
- Formalin
- Glasial acetic acid
- Glucose
- Hydrochloric acid
- Hydrogen Peroxide 3%
- Iodine-potassium Iodid solution
- Litmus solution
- Manganese dioxide
- Methyl cellulose
- Methylene blue
- Phenol red
- Peptone
- Sodium bicarbonate
- Sodium hydroxide pellets
- Yeast

* Equipment and Techniques for the Biology Teaching Laboratory

† Grobman, Arnold et. al. **BSCS Biology, Implementation in the Schools**, 1964 Biological Sciences Curriculum Studies Bulletin #3, chapter 6.

TEACHER LABORATORY AIDS

INTRODUCTION

A biology teacher needs a wide spectrum of skills and techniques as well as a directive which gives the **what and how** of growing organisms A thru Z, and methods of making up solutions and stains. This section is not exhaustive, but is just a start, for each teacher will soon realize that he needs some reference books that can better help him than the following aids. In many instances the following can be purchased already prepared with very little more cost than buying the ingredients. This will especially be true if the teacher's time and effort is considered worthwhile. The purpose of this section is to give some general information and references as where to look for more detailed and specific help.

I. MEDIA

Below are listed some growth media for a variety of organisms. Environmental conditions beyond this must be obtained from references.

TO GROW ALGAE

This needs light, a temperature of approximately 22 degrees Centigrade, and a covering which allows for exchange of gases.

1. TYPE A MEDIUM: Dissolve in 1000 ml distilled water the following minerals. Use undiluted liquid media for algae growth.

Dipotassium phosphate (K_2HPO_4)	1.25 g
Magnesium sulfate ($MgSO_4$)	.25 g
Potassium nitrate (KNO_3)	1.00 g

2. TYPE B: Bristol's Solution: Also for hydroponics

Step 1: Prepare major element stock solution by making a stock solution of EACH of the following salts by dissolving the quantity of the salt in 400 ml distilled water.

Ra Cl_2	10.0 g
$MgSO_4$ 7 H_2O	3.0 g
NaCl	1.0 g
$NaNO_3$	10.0 g
K_2HPO_4	3.0 g
KH_2PO_4	7.0 g

Step 2: Prepare Trace Element Solution as follows.

$CuSO_4 \cdot 5H_2O$	0.03 g
H_3BO_3	0.10 g
$MnSO_4 \cdot 4H_2O$	0.15 g
$LnSO_4 \cdot 7H_2O$	0.10 g
Distilled water	1.00 liter

Step 3: Prepare a 1% $FeCl_3$ Solution.

Step 4: Prepare Bristol's Solution as follows:

940 ml distilled water
10 ml of **each** major element stock solution
1 drop of the 1% ferric chloride solution
2 ml of the trace element solution

TO GROW BACTERIA: Refer to V techniques. Temperature 30-37 degrees C., no light.

1. NUTRIENT AGAR OR NUTRIENT BROTH

This can be purchased more economically already in dry weight proportions for normal laboratory use. If you wish to prepare it yourself, combine as follows:

Agar	15.0 g	(For broth omit the agar)
Beef extract	3.0 g	
Peptone	5.0 g	
Distilled water	1.0 liter	

Heat the water just below boiling and dissolve the agar. Then, add peptons and beef extract. Adjust pH to 6.8 - 7.0.

TO GROW PROTOZOA: Temperature 22 degrees C., no light.

The following two media are multi-supportive and can be prepared as stocks or ready for use. The stock quantities are given. To use, dilute one part stock with 100 parts distilled water. (If you do not desire a stock solution, divide 100 into each salt quantity, dissolve in 100 ml water and use undiluted.)

1. CHALKLEY'S SOLUTION: Synthetic pond water. General. Amoeba.

Distilled water to	1.01 liter
$CaCl_2$	0.6 g
KCl	0.4 g
NaCl	11.0 g

2. HAHNERT'S SOLUTION: Synthetic pond water. General. Amoeba.

Distilled water	1.0 liter
$CaCl_2$	0.4 g
$CaH_4\ (PO_4)_2$	0.2 g
$Ca_3\ (DO_4)_2$	0.2 g
KCl	0.4 g
$Mg_3\ (PO_4)_2$	0.2 g

3. KLEB'S SOLUTION, MODIFIER

This medium will support euglena. It is a stock solution. To dilute one part one part media with ten parts water. Grow in light.

Bacto typtophane broth	0.01 g
$Ca\ (NO_3)_2 \cdot 4H_2O$	1.00 g
KH_2PO_4	0.25 g
KNO_3	0.25 g
$MgSO_4$	0.25 g
Distilled water to	1.00 liter

4. LITTORALIS (L) SOLUTION: For the culture of **Hydra** or **Planaria** (flat worms)

Step 1: Prepare the stock solution below.

$CaCl_2$		26.6 g
NaCl	133.0 g	133.0 g
Demineralized water to		1.0 liter

Step 2: Prepare the stock solution below.

$NaHCO_3$	38.0 g
Demineralized water to	1.0 liter

Step 3: Use 10 ml of each of the above stock solutions and dilute up to a gallon with demineralized water.

To slow down Protozoa for observing under a microscope, refer to III Reagents number 5.

TO GROW DROSOPHILA: Temperature 20-24 degrees C., no light.

1. CORN MEAL MEDIUM

Agar	15 g
Distilled water	750 ml
Corn meal	100 g
Karo Syrup	135 g
Tegosept, 10%	1 ml (dissolve in alcohol) (Refer to #11 under Reagents)

Add agar to water and heat to dissolve. Add the corn meal. When the mixture boils add Karo syrup. Boil five minutes. Remove from the heat and add tegosept (mold inhibitor). If you lack a mold inhibitor, sterilize for twenty minutes at fifteen pound pressure instead. Immediately prior to using, activate by sprinkling dry yeast on surface or dissolve yeast in water and add a few drops to surface of media in culture bottle.

2. BANANA MEDIUM

A rapid, temporary medium could be mashed bananas.

3. Short Cuts to Profitable Genetic Investigations with **Drosophila** by C.T. Lange, Clayton High School, Clayton, Missouri.

The major difficulties associated with classroom investigations in Genetics with **Drosophila** revolve around the preparation of media, which generally is the minor difficulty and the establishment of mating pairs where the female is a known virgin. The following will elucidate a procedure which if followed will assure absolute success on both counts noted above.

Media Preparation:

Pour 375 ml of water into each of two 1000 ml beakers. Add 100 grams of corn meal to one of the beakers and place this into a pressure cooker. Add 15 grams of powdered agar and 135 ml of molasses to the water in the second beaker. Place this beaker in the pressure cooker and steam both beakers until the agar has dissolved. This can be accomplished by closing the lid of the pressure cooker while leaving the vent on the cooker open. After cooking the ingredients, it will be noted that the corn meal has formed a solid plug of corn meal mush in the beaker. Use a table knife to cut the corn meal into three pie-shaped segments. Transfer one of these segments to a Waring Blender cup, add eight grams of Brewer's dry yeast, U.S.P. and 2.5 ml of a 10% Tegosept M in 95% grain alcohol solution. Then add one-third of the water, molasses, agar mix and blend for a few minutes. The media will attain a fine consistency which pours easily into quarter-pint milk bottles, or it can be dispensed into rearing vials or test tubes with a 10 ml syringe.

An injecting syringe of the type used to prepare biological specimens works especially well for vial or tube dispensing. Repeat the above with the other corn meal segments. Rapid handling of the hot media once it has been blended is suggested. It pays to have all containers which are to have media dispensed into them ready for filling before the media materials are removed from the pressure cooker. Plug the containers with cotton. Milk bottle caps may be used on the milk bottles.

Establishment of Mating Pairs:

The wild and different mutant cultures of **Drosophila** should be raised in quarter-pint milk bottles, or bottles of similar size. Provide a strip of folded paper towel for the larvae to crawl up on to pupate. Once there is an abundance of pupae, the active flies can be shaken from the stock culture bottles and individual pupae cases from the paper towel can be transferred to small medial filled vials. Use a dissecting needle to loosen the pupae cases from the paper and then transfer them to fresh tubes. Place one pupae case for each strain desired in a mating cross into a fresh media vial. When the flies emerge, they can be sexed by observation with a hand lens while still in the vials. If sufficient tubes are prepared one will be assured of getting a male-female pair of the desired phenotypes. Tubes representing reciprocal crosses should be labeled. Where two males or two females of the strains being crossed end up in the same tube or vial they can be made to accomplish the desired crosses. Shake out the parental pair when larvae begin to appear and hold the tube for emergence of the F_1. After classification of the F_1 flies, the F_2 generation can be raised from the F_1 in larger rearing bottles. Pooled data from tubes in which a given mating pair were crossed will give prodgeny numbers sufficient for statistical analysis.

Suppliers:

Brewer's dry yeast – Nutritional Biochemicals Corp., 21010 Miles Ave., Cleveland 28, Ohio. Tegosept M – Goldschmidt Chemical Corp., 153 Waverly Place, New York 14, New York. Stock cultures of Drosophila from Curator of Drosophila Stocks, Genetics Research Unit, Cold Spring Harbor, Long Island, New York.

4. REFERENCES FOR MEDIA

Manual of Bacteriological Methods
Drosophila Guide
Culture of Freshwater Invertebrates
Source Book for Biological Science

To grow Hydra or Planaria refer to Section on Litteralis Solution.

II. SOLUTION PREPARATION

In considering solution preparation, perhaps a review of the three basic terms is needed:

SOLUTE – the basic ingredient to be dissolved, also serves as the name of the solution.

SOLVENT – the liquid used to dissolve the solute.

SOLUTION – the combination of solute and solvent.

CAUTION: Always add acid to water.

1. PERCENTAGE BY WEIGHT

Water is used as the solvent for most biological solutions. The formula obtaining percentage solutions by **weight** is:

$$\text{grams of solute} = \text{\% by weight of solution} \times \frac{\text{desired quantity of solvent ml}}{100}$$

2. PERCENTAGE BY VOLUME

The general rule is: Find the concentration of the dilute solution required; then add in amount of diluent to bring the total volume up to the numerical value of the concentrated solution.

Example: A 50% solution of ethyl alcohol is wanted and must be prepared from a stock bottle containing 70% alcohol. Measure 50 ml of 70% alcohol in a graduated cylinder and add 20 ml water to bring the total volume up to 70 ml (the percentage of the original solution).

3. MOLAR SOLUTIONS (M)

A molar solution contains 1 gram-molecular weight of the dissolved substance in 1 liter of solution.

Example: Atomic weight of H = 1, of Cl = 35.5, therefore the molecular weight of HCl = 36.5

A 1 M HCl solution contains 36.5 g of HCl in 1 liter of solution.

4. NORMAL SOLUTIONS (N)

A normal solution contains 1 gram-equivalent weight of the compound in a liter of solution. A gram-equivalent weight of a compound is equal to the gram-molecular weight divided by the total valence of its positive or negative ions.

Example: $\frac{\text{g-mol. wt. } H_2SO_4}{\text{total positive ions} = 2} = 49 \text{ g } H_2SO_4$ per liter to form a 1 M solution.

5. DILUTION OF SOLUTIONS

To dilute a solution follow the general pattern:

$$X \text{ ml solute} + Y \text{ ml of dilutent} = \frac{X \text{ parts solute}}{Y + X \text{ parts solution}}$$

Example: To obtain a solution of 0.01 concentration (= 1% or 1 x 10^{-1})

$$\frac{1 \text{ part solute}}{100 \text{ parts solution}} = 1 \text{ part solute} + (100 - 1) \text{ part dilutent}$$

(Note that the fraction is the desired concentration.)

Example: If you have a 0.1 solution and desire a 0.05 solution

$$10 \text{ ml of } 0.1 \text{ soln.} + 10 \text{ ml water} = \frac{10 \text{ parts of } (0.1)}{20 \text{ parts solution}}$$

Therefore the final concentration = (0.1) (0.5) = 0.05.

III. REAGENTS

1. BENEDICT'S SOLUTION (This may be purchased already prepared.)

Use to test for a reducing sugar; i.e. glucose, sucrose, etc.

Step 1: Prepare the solution of:

Sodium citrate (crystalline)	173 g	
Sodium carbonate (anhydrous)	100 ml	FILTER
Distilled water	800 ml	

Step 2: Prepare the solution of:

Copper sulfate	17.3 g
Distilled water	100.0 ml

Step 3: Combine the 2 solutions and add water so total volume equals 1 liter. (Fehlings A and B are synomous with these.)

TO USE: 1 part material to be tested, 5 parts Benedict's, 5 parts water. Heat gently, a red color denotes the presence of a reducing sugar.

2. BIURET'S REAGENT

This is used to test for proteins. Prepare the following two solutions: 20% NaOH and 1% $CuSO_4$. To test for protein, combine 1 cc of the 20% HaOH with 5 cc of the protein in water. Mix. Add 1 or 2 drops 1% $CuSO_4$. A violet color denotes proteins. A rose-pink color denotes peptones. (Million's Reagent is another for testing proteins. Since it is made with mercury, it is quite expensive.)

3. BROMOTHYMOL BLUE

This is an indicator with a narrow pH range, 6.0 - 7.6. The solution is yellow when acid and blue when basic. To prepare a 0.1% stock solution:

Bromothymol blue	0.5 g
Distilled water	500 ml
NH_4OH	trace (enough to turn solution blue)

4. METHYL CELLULOSE – To slow down protozoa

This reagent is used to slow down protozoans and other small microaquatic organisms. Either sprinkle the powder on the microscope slide or use a 10% aequous solution.

5. PHYSIOLOGICAL SALINE SOLUTION

Use to stimulate and sustain life in pithed animals.

Type A: RINGER'S SOLUTION – Use with cold blooded animals.

$CaCl_2$	0.12 g
KCl	0.14 g
$NaCl$	6.50 g
$NaHCO_3$	0.20 g
Distilled water	1.00 liter

Type B: RINGER'S SOLUTION – Use with warm blooded animals.

$CaCl_2$	0.24 g
$NaCl$	9.00 g
KCl	0.42 g
$NaHCO_3$	0.20 g
Distilled water	1.00 liter

6. POTASSIUM DICHROMATE CLEANING SOLUTION

Frequently, it is necessary to have glassware virtually "mineral free." The following solution is very effective but caustic to skin and clothing and therefore dangerous to handle. Store in plastic container with wide mouth.

Step 1: Prepare the following solution in 1 liter flask.

Potassium dichromate	40 g
Distilled water	150 ml

Step 2: SLOWLY add 250 ml concentrated sulfuric acid. Add in a few ml at a time, swirl solution. Cool periodically in a cool water bath. The solution has a dark red crystal in a dark liquid. It turns greenish when it wears out.

TO USE: Pour into container to be washed, swish about, and pour back into storage vessel. Rinse 5x with water before using the container. For stubborn areas; soak in the solution overnight.

7. ACID AND BASE REAGENTS

		HCl	HNO_3	$HC_2H_3O_2$	H_2SO_4	H_3PO_4	H_4OH
COMPOSITION OF COMMERCIAL STANDARD REAGENTS	Molecular Weight	36.4	63.01	60.054	98.08	97.99	35.048
	Approx. specific gravity	1.19	1.42	1.05	1.84	1.70	0.90
	Approx. percent strength (assay)	37.2	70.0	99.8	96.0	85.5	57.6
	Molarity of Commercial Reagent	12.1	15.8	17.4	18.0	14.8	14.8
	Normality of Commercial Reagent	12.1	15.8	17.4	36.0	44.4	14.8

PRECAUTION: Always add acid to water HINT. AA Add Acid

PREPARATION OF LN ACID	HCl	500 ml. water + 500 ml. acid	
	HNO_3	610 ml. water + 390 ml. acid	CARE – Heat
	H_2SO_4	832 ml. water + 168 ml. acid	generated
	$HC_2H_3B_2$	655 ml. water + 345 ml. acid	

PREPARATION OF L N ACID	HCl	918 ml. water + 82.5 ml. acid
	HNO_3	936 ml. water + 63.5 ml. acid
	H_2SO_4	945.5 ml. water + 55.5 ml. acid
	$HC_2H_3O_2$	942.5 ml. water + 57.5 ml. acid
	H_3PO_4	932.5 ml. water + 67.5 ml. acid

PRECAUTIONS:
1. Weigh solids on watch glass or in beaker – NOT ON PAPER.
2. Weigh quickly and do not let particles fall on scale or table.
3. Add solid base in small portions with stirring to water.

HINT: AB Add Base

PREPARATION OF 6N BASE

NaOH (Mol. Wt. -39.99) 240 gms. dissolved in 800 ml. water.
KOH (Mol. Wt. -56.108) 336.6 gms. dissolved in 750 ml. water.
NH_4OH (Mol. Wt. -56.108) 405.5 ml. in 595 ml. water.

NaOH	42 grams dissolved in 960 ml. water.
KOH	56 grams dissolved in 900 ml. water.
NH_4OH	67.5 ml. in 933.3 ml. water.

PREPARATION
OF 1N BASE

SUGGESTION: To make up a liter of a certain normal solution from commercial reagent.

Required solution________Commercial reagent
ml. X N______________ml. X N

Add the calculated number of ml. of commercial reagent to some water and then continue to dilute to a liter of solution.

REMEMBER: In making up PERCENT SOLUTIONS, you do not consider the molarity of the commercial reagent. You use specific gravity and consider the number of grams of acid or base per hundred.

8. CARNOY'S FLUID

Use to preserve hard-shelled specimens. The solution is highly POISONOUS and INFLAMMABLE. Do not prepare until just prior to use.

Absolute alcohol	.33 ml
Chloroform	.33 ml
Glacial acetic acid	.33 ml
Mercuric chloride	.25 g (enough to saturate)

9. CARL'S SOLUTION

Use to preserve insect forms.

Alcohol (95%)	179 ml
Formalin (40% formaldehyde)	60 ml
Distilled water	280 ml

Just before using, add 20 ml glacial acetic acid.

10. FUNGICIDE FOR DROSOPHILA MEDIA

Tegosept	10 g
Alcohol (95%)	90 ml

Add to the media.

11. FUNGICIDES FOR SEEDS

a. Ethyl or isopropyl alcohol 70% . . . . soak seeds for one minute.
b. Formaldehyde . . . . formalin diluted 1:500 . . . . . .soak seeds twenty minutes.
c. Sodium hypochlorite . . . . .dilute commercial bleaches (chlorox) 1:4. Soak seeds fifteen minutes.

IV. STAINS

1. METHYLENE BLUE

Good stain for protozoans.

Methylene blue	0.3 g
Ethyl alcohol (95%)	30.0 ml

When dissolved add 100 ml water.

2. ACETOCARMINE

To fix and stain nuclear materials, especially chromosomes.

Step 1: Combine carmine in acetic acid until some of the powder will not dissolve.

Carmine	excess
Acetic acid, glacial	45.0 ml

Step 2: Add 55 ml distilled water. Bring the solution to a boil.
CAUTION: This must be done under a fume hood with adequate ventilation. Cool and filter before using.

3. ACETOORCIEN STAIN

Same purpose as Acetocarmine. Use orcien in stain solution instead of carmine with same mixing procedure.

4. CONGO RED VITAL STAIN

Add 0.1 g congo red to 100 ml distilled water. Dissolve. It may be necessary to filter before using.

5. IRON-ACETOCARMINE

Add a few drops of Aqueous ferric acetate solution to the above acetocarmine until the color is a dark wine red.

6. GIEMSA STAIN

Use for staining blood smears. Prepare in quantities of 100 ml to 5 liters.

Step 1: Put absolute alcohol or alcohol-glycerine mixture into **covered**, dry hard glass flask.

Step 2: Add 50 large dry glass beads and dry dye mixture to flask.

Step 3: Agitate this mixture by rotating the flask for 2 minutes every half hour. (To be done six times.) By using covered flask, the stain will not absorb water, thus the life of the stain will be longer.

Stains used for Gram Stain of Bacteria

7. GRAM'S IODINE

Iodine	1.0 g
Potassium iodide	2.0 g
Distilled water	300.0 ml

8. HUCKER'S CRYSTAL VIOLET

Step 1:	Crystal violet	2 g
	Ethyl alcohol (95%)	20 ml
Step 2:	Ammonium oxalate	1 g
	Distilled water	100 ml

Step 3: Combine the 2 solutions.

9. SAFRANIN

Mix the ingredients, allow to stand for two days, stir during this time. Filter before using.

Safranin	3.41 g
Ethyl alcohol (95%)	100.00 ml

PROCEDURE FOR GRAM STAINING OF BACTERIA

1. Heat to fix the bacteria on the slide.
2. Add Hucker's crystal violet. Allow to stand for sixty seconds. Rinse.
3. Add Gram's iodine. Allow to stand for sixty seconds. Rinse.
4. Add 10 drops of ethyl alcohol.
5. Add Safranin. Allow to stand for thirty seconds. Rinse and blot.

V. TECHNIQUES

A. SLIDE PREPARATION

1. GENERAL FACTORS

a. All tissue should be as small as possible, allows for better penetration.

b. A large amount of fixative should be used to prevent its being diluted by tissue fluids.

c. Fixation should be limited to proper time limit, because fixatives may over-harden or macerate tissues.

d. Many common fixatives must be allowed by proper washing procedures.

2. FIXATION OF TISSUES

Proper agents should be used in fixation to prevent postmortem changes and should be administered according to the effect and fixation desired.

COMMON AGENTS

a. Acetic acid – kills very rapidly and produces excellent differentiation.

b. Alcohol – penetrates very rapidly.

c. Chromic acid – used in combinations, gives excellent cytological detail.

d. Commercial – gives average fixation, penetrates well, and hardens well.

e. Mercuric chloride – shrinks tissue strongly, must be washed out. Gives excellent differentiation of cellular detail.

f. Osmic acid – mordants chromatin and darkens body fats. Gives very poor penetration.

g. Picric acid – is not used alone because it causes drastic shrinkage.

h. **FAA**
To fix plant material for staining purposes, place into the following solution for ten minutes.

Ethyl alcohol (95%)	50 ml
Glacial acetic acid	2 ml
Formalin (40% formaldehyde)	10 ml
Distilled water	40 ml

3. DEHYDRATING AND CLEARING

Any object which is to be embedded in a resinous material or paraffin must be dehydrated and cleared first. This step is accomplished by replacing the water in the tissue with alcohol and then replacing the alcohol with a chemical which is miscible with the embedding material. By using a reagent which is both miscible in water and in the media, we can cut this procedure to one step.

The use of absolute alcohol is very good for dehydrating. It is recommended to use this on the tissue in a dilution series. Starting with 15%, 40%, 75%, 95%, and 100% absolute alcohol, we can eliminate all undesired effects of straight alcohol on the tissue and thus the dehydrating process can be handled by hand.

Isopropyl alcohol and cellosolve, a reagent, are used to both dehydrate and clear in one step. The cellosolve is thicker than alcohol and thus must be used in a more extended series of dilutions.

Recommended clearing agents are oils and hydrocarbons. The oil which is the most practical and gives the best results is terpineol; it should not be used to clear prior to embedding in paraffin. The most widely used hydrocarbons are benzene, xylene, and toluene. They are used to clear both for paraffin and the mounting media. Since hydrocarbons are miscible in paraffin, they can be used before embedding but only after complete dehydration has taken place.

4. PARAFFIN BOATS FOR EMBEDDING

Small plastic boxes of polyethylene or small transparent styrene boxes are excellent containers to embed tissues. Because the boxes are transparent, one can orient tissues precisely in melted paraffin. Also, the paraffin does not adhere to the plastic boxes and as it hardens the mass contracts evenly giving a less distorted box.

5. "A COVERSLIP RACK FOR STAINING"

The rack is made from a very fine-toothed, hard rubber baby comb having teeth on both sides. Because of the teeth, the comb must be cut in half and sanded smooth. The comb should now be trimmed to about 3½ inches. Next, drill a ¼ inch hole through the solid part ¾ inches from each end and ⁵⁄₁₆ inches from the back edge.

Take a two foot piece of # 10 steel wire and cover with Tygon tubing (⅛" bore, ¹⁄₁₆" wall). Bend the wire into two legs so that they are parallel and about 2" apart. Soak this in xylol overnight to shrink Tygon. Thread first comb onto the legs of the covered wire until it is about 3" from the closed end. Next thread ½" long piece of Tygon (¼" bore, ¹⁄₁₆" wall) onto both legs. These act as spacers. Now add another comb and next pair of spacers ¼" long. Continue until seven comb halves and six spacers are in place alternating spacers lengths. The wire is then bent up in the direction of comb teeth and at a 90 degree angle on each side of the combs. The open end is bent to form a loop and the ends are fastened together with a piece of ⅛" tubing. Overall dimensions: 3½" wide x 4½" long x 3" high.

B. BACTERIA

1. HANDLING

All bacteria should be handled as if they were pathogenic, which is only good laboratory technique. This kind of procedure will also prevent contamination of pure cultures. Clean working surface with a wet paper towel, or a 2 to 5 percent solution of cresol may be used. Close windows to prevent air currents which have a tendency to contaminate cultures.

Most bacteria grow best at a temperature of 37 degrees centigrade. Cultures may be kept stored in the refrigerator for use at a future time.

Fill a test tube ⅓ full with melted nutrient agar. Plug with cotton and sterilize. Remove from the sterilizer and lay upper end on a rolled-up towel so that when laid down the agar will not touch the cotton plug. When cooled, the slants can be inoculated with bacteria and stored as cultures.

If experience is lacking, a bacteriology laboratory manual should be consulted.

2. STERILIZATION

Media, transfer equipment, and culturing apparatus necessary for microbial work must be sterilized.

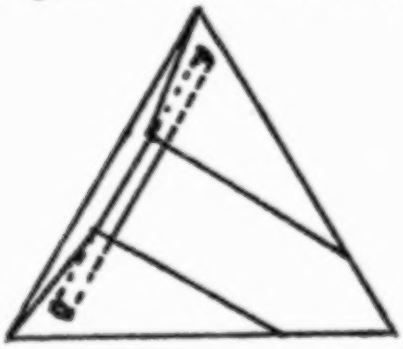
a. STEAM

Media and media containers can be sterilized in pressure cookers. A 21 qt. size cooker will sterilize 28 Erlenmeyer flasks. One must use a heat source equivalent to 1,200 watts. This requires a large burner. Add a small amount of water (not higher than the rack on the bottom), and the materials to be sterilized to the cooker. Place on the lid with the exhaust valve OPEN. Keep the exhaust valve open until there is a continuous flow to steam. (Closing it prior to this will lower the temperature.) Allow a pressure of 15 lbs. to be formed and time for twenty minutes. The pressure must be allowed to fall gradually or the plugs will be popped.

b. DRY

Petri dishes and pipettes can be sterilized in the oven. The pipettes should be wrapped individually in newspaper and sealed. A number of them should then be wrapped together in aluminum foil and placed in the oven. There are metal pipette cans available in which many can be sterilized at one time. A number five juice can makes an excellent container for Petri dishes during sterilization. The tops should be covered with aluminum foil. The time for sterilization is dependent upon the quantity of material in the oven, the type of material and the temperature.

At 165-170 degrees C, it takes approximately two hours, whereas at 400 degrees C it takes only thirty minutes.



How to Roll Pipettes in Newspaper

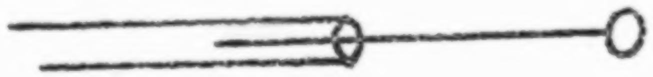
3. TRANSFER EQUIPMENT

a. NEEDLES AND LOOPS

Use 0.5 mm I.D., capillary glass or aluminum tubing for handles. Insert about 3 cm of 8 cm piece of #24 Nichrome wire into the tubing, fire and seal. This wire can be purchased in rolls or in cut pieces.

b. PIPETTES

These can be made from glass tubing. A good diameter is 5 mm O.D. glass tubing. Cut the glass tubing into 24 inch lengths. Heat the center and pull to constrict. Break at mid-point and fire polish all ends. Attach the glass tubing to a ring stand and connect to a syringe via a rubber tube. Inject water into the tube. Mark the tube. Extract the desired calibration and mark the tube.



VI. CHEMICAL GRADES

1. A.C.S.

Chemicals which meet the specifications of the American Chemical Society for an analytical reagent.

2. C.P.

   Chemicals of very high chemical purity. The A.C.S. and Reagent labels are replacing them on the market, but can be used for quantitative and qualitative analysis.

3. PRACTICAL

   A few impurities, but usually ranges from 95 to 98% pure.

4. PRIMARY STANDARD

   Chemicals which have been produced to give maximum physical uniformity and purity and have been carefully checked.

5. PURIFIED

   Good for most general uses, but the quality is without official standards.

6. REAGENT

   Chemicals produced with the highest feasible purity according to manufacturers specifications. The label will have analysis showing standard of purity and limit of impurities. The reagent or A.C.S. grades are best for quantitative analysis.

7. TECHNICAL

   A chemical of commercial quality and of reasonable physical and chemical purity.

8. U.S.P. and N.F.

   Meets standards set up by Pharmacopeia of the United States and the National Formulary. The two grades are essentially interchangeable and are suggested as satisfactory for qualitative analysis and purposes which do not require a high degree of purity. These grades are of the minimum purity that should be used for biological purposes.

VII. RADIATION LABORATORY

1. RADIOAUTOGRAPHY by C.T. Lange, Clayton High School

The concentration of specific radioactive elements in biologic systems can be determined by use of unexposed film using a technique called radioautography. The general procedures for handling radioactive specimens and film exposure follows:

All specimens that have been exposed to situations where they may absorb radio-active isotopes must be handled in accordance with safety regulations. Always keep radio-isotope solutions and specimens in a tray lined with absorbent paper. Never place specimens in a window or elsewhere where they might be knocked over by the wind or by busy people brushing by. Spilled radioactive materials are a hazard in the laboratory. They cannot be wiped up like spilled milk. They must be handled and cleaned up in special ways. If they have penetrated porous materials like cracks in the floor they must be left to decay through their normal half-life times. Approximately eight half-lives of an isotope must pass before it is reduced to less than 1% of its initial activity.

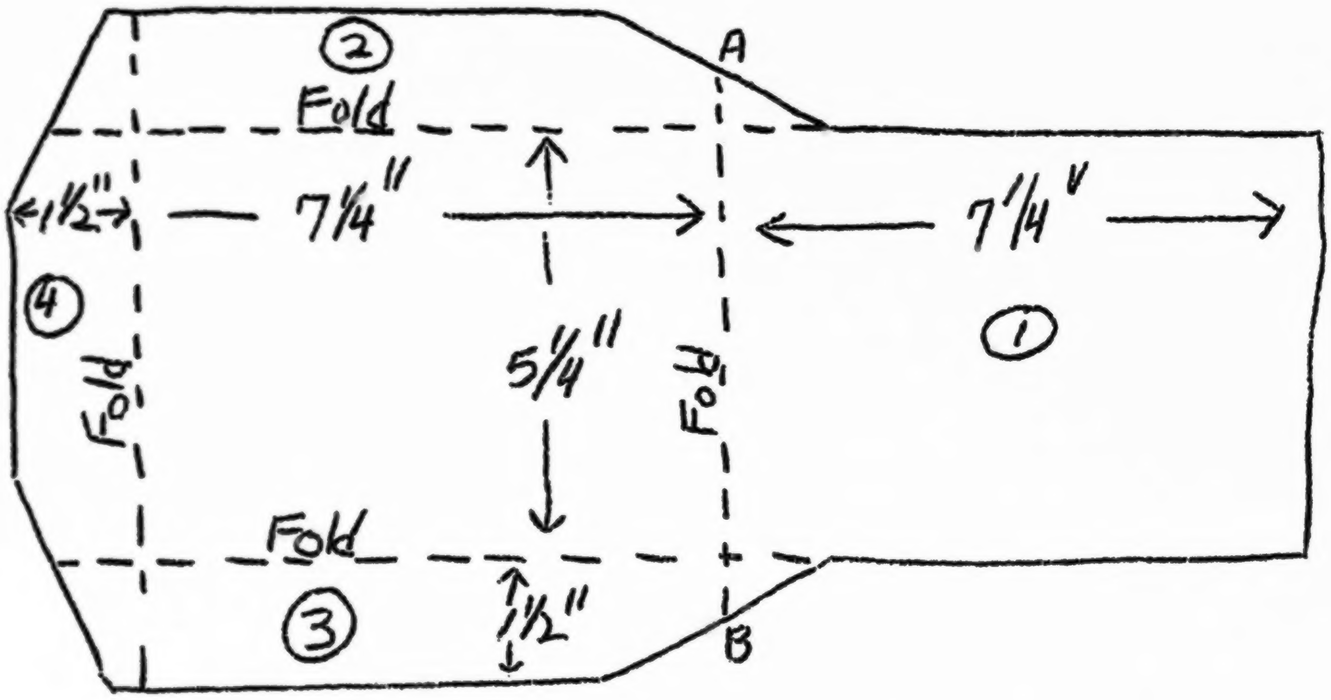
Dispose of all specimen materials in a careful, thoughtful manner. Dumping all materials helter skelter in a box marked for isotope and other radioactive material disposal makes it doubly hard for the laboratory help to clean up in a safe manner. All liquid wastes should be disposed of in a container marked for their collection. Glassware that contains other liquids such as acids, or KOH solutions should be set upright in the disposal container. Soil in pots or other containers is best stacked in a marked container and not dumped all over the glassware.

Biologic specimens that are radioactive can be mounted on cards and covered with saran wrap in preparation for film exposure. The saran wrap will cut out some of the radioactive emmination especially with low level emitters like carbon-14. Putting tape over the specimens will further impede assay of concentration of isotopes by the film. It is best to position the specimens on the 5 x 7" cardboards and then after making identifying marks on the specimen card, the card should be covered with one layer of saran wrap. Keep the entire card upright and fix the saran wrap tight by using tape to pull tension on the saran wrap as it is fixed to the underside of the card. Label all specimen cards with radioactive warning tape.

Proper exposure times can be determined, in most cases, by making a geiger counter assay of the activity levels of the specimens. About 1,000 counts per minute from the specimen means that an exposure of about 16 hours will be required. In many cases, common sense will dictate the exposure time. Weak emitters (consult tables of physical Re. isotope in question) will require long exposure times. With isotopes like carbon-14 or sulfur-35 exposure times of a week or more in order.

Once specimen cards have been prepared and the residue of the experiment has been disposed of in a proper manner, the film exposure can be set up. Medical no-screen X-ray film can be placed against the saran-wrapped specimen. This should be done in a dark room or in a dark box. A dark box with dimensions of 12 x 12 x 24" with four equally-spaced shelves and a light tight sliding front closure with black cloth sleeves will do. Use the dark box for film loading and later development. The four-shelf dark box should be used as follows: KEEP THE TOP SHELF DRY AT ALL TIMES for film loading and unloading; the second shelf should be reserved for the tray of developer; the third shelf for a water wash or short stop bath (acetic acid); and the lower shelf for the acid fix bath.

Films should be loaded against specimen materials using a film holder. A 5 x 7" film holder can be prepared as follows:



FOLDING PLAN FOR FILM HOLDER

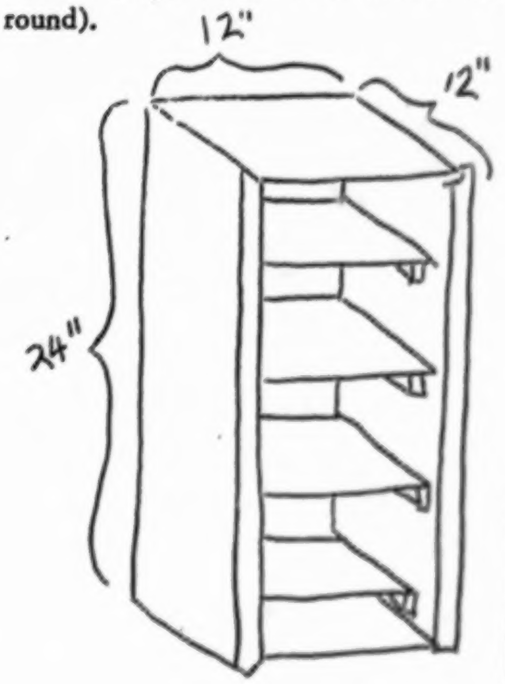
Cut film holder from black or some other opaque paper. Fold as indicated. Mount the folded light tight envelope between two heavy cardboards 7½ x 5½". The hinge of the film holder cardboards should be along folded line indicated A-B.

The proper sequence for folding the flaps of the film holder is indicated by circled numbers on the diagram above. The flaps must be folded in the proper manner so as to assure a light tight envelope for film exposure. With the specimen and a sheet of unexposed film in the holder the flap marked #1 must be closed first. Then the side and flaps should be folded closed. The overlap of paper at the corners serves to give a light tight seal. Use rubber bands or paper clips to hold the film holder cover closed. Weight the film holder with books or arrange some other way to press the holder so as to bring the film into direct contact with the saran wrap covered specimens. After proper exposure, return the film holder with contained specimen and film to the dark room or dark box and remove the specimen card. The film may be developed immediately or it can be left in the properly closed film holder for development at a later time. It is not good practice to stack film holders that contain specimens and film being exposed. Strong emitters such as P-32 will give off emission which will penetrate the film holder covers and fog film in adjacent holders.

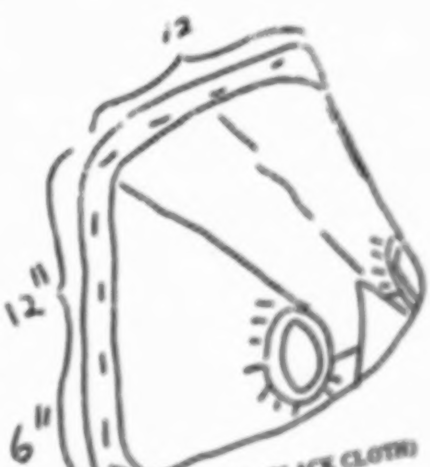
After exposure the film should be developed as follows:

The procedure for using a dark box will be noted. This same procedure should be followed if working in a darkroom. The film development sequence is: 1. Developer (4 minutes); 2. Water wash or short stop rinse (thirty seconds); 3. Acid fix or "Hypo" (five minutes or until clear): 4. and finally a thirty-minute water wash.

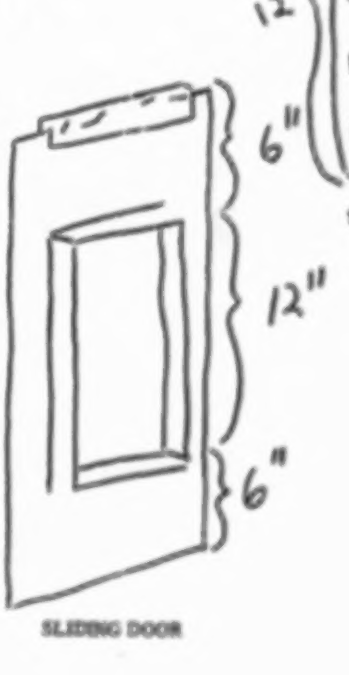
In the dark box you will proceed in the following manner: Place the film holder on the top dry shelf. The film developer (X-ray film developer or Kodak MQ universal developer) is placed in a tray on the second shelf. The tray on the third shelf should have water or short stop (acetic acid mixture) in it. Acid fix or "hypo" should be in the tray on the bottom shelf. Time the development as follows: four minutes in the developer (68 degrees F.), rinse in the water or short stop; place in the acid fix for five-ten minutes or until clear. Milky areas on the film indicate the need for longer acid fix treatment. Remove the film from the dark box and rinse in a tray of running water for thirty minutes. Hang the film up to dry. When working in the dark box, the arms must be inserted into the black sleeve past the elbows. This will prevent light leaks, assuring proper film film loading and/or development. A convenient one-package unit that includes developer, short stop and acid fix is the "Kodak" Tri-Chem pack. The tri-chem pack contains Kodak Dektol developer, Kodak universal stop bath, and Kodak universal fixer. Medical no-screen X-ray film can be loaded with either side to the specimen as emulsion is on both sides of the film. The dark box used to load films and for development of films is diagrammed below. Materials: ¼" plywood; heavy black material for sleeves; 1 x 1" pine for framing; ¾" molding (¼-round).



CABINET (Shelves 11" x 6")

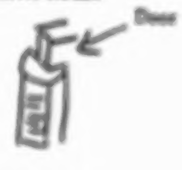


SLEEVE DETAIL (BLACK CLOTH)



SLIDING DOOR

Molding Detail
(Inside)
Quarter Round



(Outside)
¾" Round
Round Stock

2. ACTIVITY CALCULATIONS FOR RADIOISOTOPE SAMPLES by C.T. Lange

Radionuclide materials as furnished by educational supplies are calibrated to a given date, usually the date of delivery to the school. Rate of nuclear activity in disintegrations per minute (D/M) can be determined by following the method noted below. The procedure listed below will give figures that are applicable to the activity on the calibration date of the radioisotope in question. Activity figures for dates following the calibration date will require additional calculations.

The activity of radioisotopes is generally expressed in parts of a unit called a Curie (C).

1 Curie equals 3.70×10^{10} disintegrations per second (D/S)
1 Curie equals 2.22×10^{12} disintegrations per minute (D/M)

One one-thousandth of a Curie is expressed in terms of Milli-Curies (mc) or

1×10^{-3} Curie
1 Curie equals 1×10^{3} Milli-Curies (mc)

One one-millionth of a Curie is expressed in terms of Micro-Curies (Mc) or
1×10^{-6}
1 Curie equals 1×10^{6} Micro-Curies (Mc)

Metric measure of liquid volumes of isotope materials are frequently in terms of λ (Lambda) which is equivalent to a Microliter

1 microliter equals 1×10^{-6} Liter, or 1 microliter equals 1×10^{-3} milliliter

Example:

Sample of isotope p^{32} calibrated to 10 mc/10 milliliters
1 Micro-Curie of this sample will have an activity of 2.22×10^{6} D/M
1 Micro-Curie (Mc) will be contained in 1 milliliter (ml)

1 λ (Lambda) of the isotope solution will have an activity of 2.22×10^{3} D/M

If the sample used was 25 λ (Lambda) the activity will be 2.22×10^{3} D/M multiplied by 25, which is equal to 55.5×10^{3} D/M. Thus 55,500 D/M will be the activity in the sample at the date and time of calibration.

A check of the sample with a scaler-rate-meter gave an indication of about 2,000 counts per minute (C/M). According to this rate the meter obtains a measure of about 3.6% of the activity. Counting geometry considerations, and self-absorption along with air absorption and other influences account for this small measure of the actual number of nuclear disintegrations.

VIII. REFERENCES:

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SAFETY REGULATIONS FOR THE RADIOBIOLOGY LABORATORY

1. A log book containing a listing of all radioisotopes received in the laboratory (date of receipt and calibrated activity) should be maintained. Students should sign the log book indicating what radioisotope was used in a given investigation. The liquid volume and activity in microcuries of samples withdrawn from the supply bottles should also be recorded.

2. Monitor cartons and radioisotope vials on receipt of shipment (see figure 1). Surround radioisotope containers with appropriate shielding to protect students working in the vicinity.

3. Do not bring unnecessary materials into the laboratory and place on working areas. Radioactive materials spilled on personal possessions will necessitate decontamination or possible disposal.

4. Only authorized personnel are allowed in the laboratory. Children and pets should be kept out. Never allow students to handle radioisotopes in the absence of the instructor.

5. Avoid ingestion or inhalation of radioactive materials. Never eat or drink in the laboratory. Keep eating utensils out of the laboratory. Do not apply cosmetics in the radiation laboratory. Confine reactions which might evolve a radioactive vapor to a gas-tight enclosure.

6. Never pipette radioactive solutions by mouth suction. Always use a control device such as a pipette bulb or a micro-pipette syringe (see figure 2).

7. Avoid contamination of hands or clothing. Wear gloves (rubber, or plastic disposable type) when handling radioactive materials. Wear gloves when handling radioactive plants or animals. Wear laboratory aprons when working with radioisotopes.

8. Always work with radioactive isotopes over a large, shallow tray. Line the tray with an absorbent material like disposable baby diapers. Use diaper with absorbent side up and the waterproof backing to the tray. Spills in the tray will be absorbed and will not soak through the backing to contaminate work surfaces.

9. Spills can be avoided by providing support for open radioisotope vials. Clamp the vials or set them in a larger beaker for support. Wood blocks drilled to hold radioisotope vials can be used to prevent spills.

10. Handle all specimens or containers with tongs or tweezers when practical.

11. Monitor all working areas after handling radioactive materials. Check hands with a Geiger counter. The yellow civil defense V-700 Geiger survey meter can be used as an effective monitoring instrument. Wrap the G-M tube holder in a layer of saran wrap to prevent contamination of the probe with hands which may be contaminated.

12. Contaminated hands or working surfaces should be scrubbed with a soft brush. Scrub for three-six minutes, then monitor and scrub again if necessary.

13. Label all experiments with radioactive warning tape; note date and radioisotope used.

14. Do not cage animals which have been injected with radioactive isotopes in containers from which they can escape by gnawing. Animal cages should bear labels indicating the radioisotope used. Cage litter should be treated as radioactive waste.

15. Keep all radioisotope supplies under lock and key when not in use.

16. Promote familiarity with experimental procedures by making trial runs of a given technique with non-radioactive materials. Once the technique is mastered the student can move on to working with radioisotopes.

17. Radioactive waste should be kept in labeled containers. Short half-life (T½) radioisotopes in the license-exempt category can be discarded after holding for eight to ten T½ periods. Low level radioactive wastes from radioisotopes obtained without an A.E.C. license requirement can be disposed of by dilution with large volumes of water or air. An alternate and more desirable way of disposal of small liquid amounts is to mix fluids with plaster of paris in small containers and then dispose by burial in the soil.

Student Exercise in Radiation Safety and Dosimetry

Workers who handle radioactive materials are checked constantly with regard to the amount of radiation to which they have been exposed. Film badges and dosimeters worn by laboratory personnel help to keep accurate check on amounts of radiation received. A student exercise in radiation safety and dosimetry can be set up using classroom assembled film badges. Dental film packets can be used to make film badges for each student. A safety pin taped to the back tab side of the dental film packet will make it possible for the student to wear the badge each time he works in the laboratory. Student names should be marked on the front of the badge with permanent ink. A film badge chart with check-in and check-out time for each laboratory period worked will help keep tab of the hours the students are in the radiobiology laboratory.

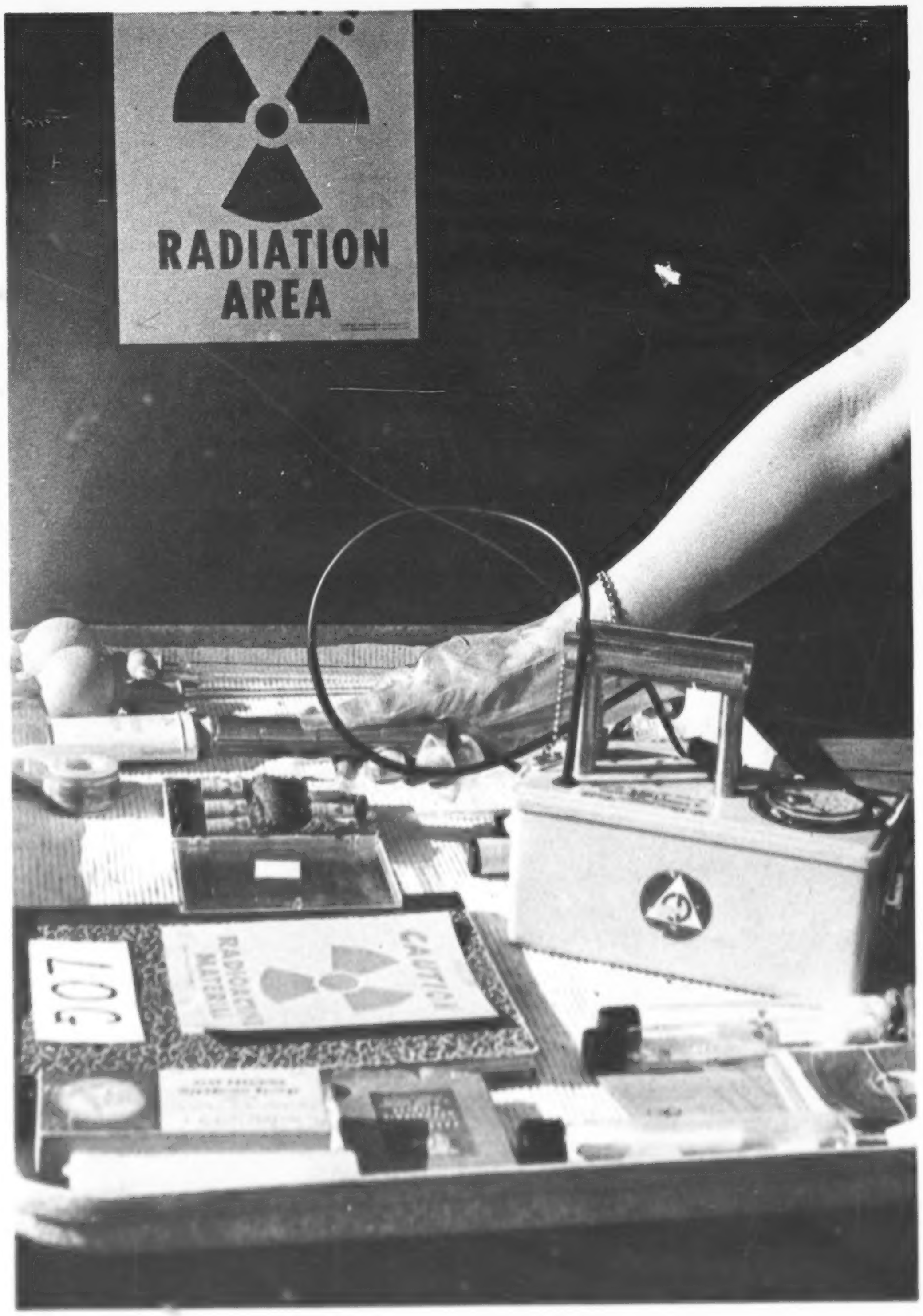
Ionizing radiations which penetrate photographic emulsions leave a latent image which can be shown on development. We are familiar with the shadow images of the human skeleton on large medical X-ray films. With no specimen between the film and the radiation source, the film will appear uniformly darkened on development.

Fresh film should be used for film badge preparation. A sample of the film should be developed with fresh developer at the proper temperature and development time at the beginning of this exercise. Old or outdated film may be fogged and appear darkened on development, thus giving a false indication of radiation exposure.

Film comparison standards for this exercise can be set up by exposing fresh film to a standard radiation reference source. If a Civil Defense V-700 survey meter has been calibrated against a standard radiation reference source it can be used to set up the local exposure of film for film comparison standards. This meter reads in milliroentgens per hour. The milliroentgen per hour readings make it possible to calculate how long a comparison film standard must be exposed to receive a given dose. The National Committee on Radiation Protection has recommended a **Maximum Permissible Dose** (MPD) for personnel working with ionizing radiations. See NBS handbook #69 for MPD or **Standards for Protection against Radiation,** 10CFR20 and Amendments. (Division of Licensing and Regulation, A.E.C.) The laboratory guide of a recent Radiation Biology Summer Institute stated, "In no case will the student be permitted to receive more than 30mr/week (whole body radiation)." While this would seem to be a safe figure to hold to for student laboratories it should be kept in mind that students under 18 years old are allowed only one-tenth of the MPD for radiation workers. Comparison standards with 5, 10, 20, 30, 60, 100, 200 and 300 milliroentgen exposures, as well as higher exposures, should be prepared.

The Civil Defense V-700 survey meter with fresh batteries can be calibrated to read 2.0 mr/hour on the X10 scale. See V-700 instruction manual for details regarding calibration. Radioactive sources for film exposure can now be calibrated. Items like the uranium oxide, orange glazed California Fiesta dinnerware of the FCDA item CD V-787 ten-day water standard from the Civil Defense kit emit sufficient radiation to expose films. Flat surfaces of the orange glazed Fiesta dinnerware give a reading of about 3.0 mr/hour; the ten-day water standard measures about 5.0 mr/hour. Thus, a ten-hour or six-hour exposure, respectively, of the film packet at a distance approximating the Geiger tube of the CD V-700 will give 30 milliroentgen exposures. Exposure times for higher or lower doses can be calculated from the above.

With the small amount of radioisotope activity that can be obtained in license-exempt quantities, it would suffice to set up film badges during the first laboratory exercises in a radiobiology unit. Students should wear the film badges each time they work in the laboratory and make an appropriate entry on the film badge chart. Students will seldom be in the laboratory through the radiobiology unit the equivalent of a normal work week, in hours, for MPD figures listed in the literature. Store the film badges in a place away from radioactive materials when not being worn. A fresh film left in the storage area throughout the radiation biology unit will provide a check of the storage area. At the end of the radiobiology unit, develop all the student badges as well as the control film. Use fresh developer at the proper temperature for the recommended time. The amount of radiation exposure for a given student film can be judged by comparison with the previously prepared comparison exposure standards.


RADIATION
AREA
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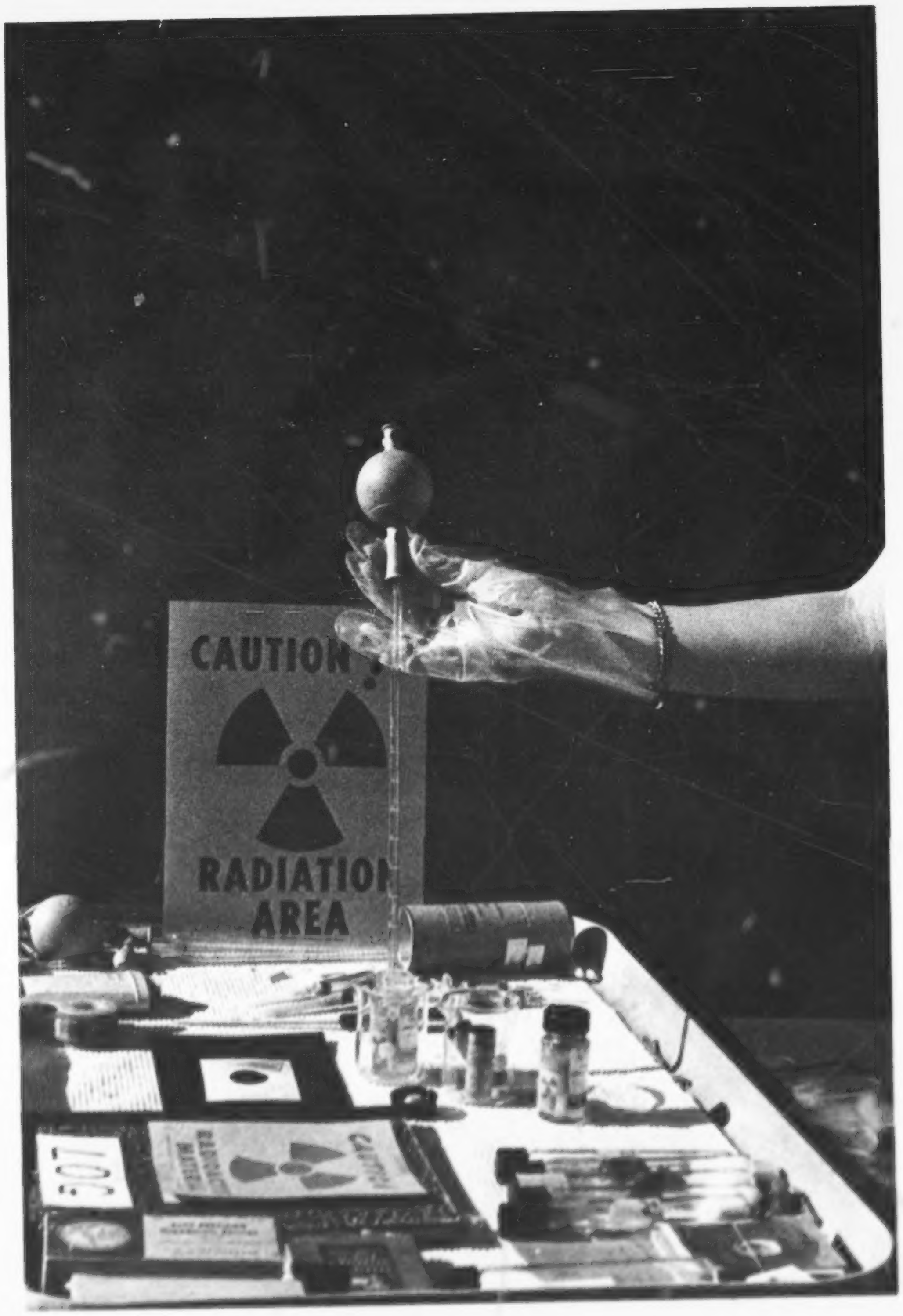
RADIOACTIVE MATERIAL
107


CAUTION
RADIATION AREA

The following reference material on radiation safety can be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

National Bureau of Standards Handbooks;

Safe Handling of Radioactive Isotopes; NBS Handbook 42. GPO. $0.20 Revision in preparation.

Control and Removal of Radioactive Contamination in Laboratories; NBS Handbook 48. GPO. $0.15.

Recommendations for Waste Disposal of P-32 and I-131 for Medical Users; NBS Handbook 49. GPO. $0.15.

Radiological Monitoring Methods and Instruments; NBS Handbook 51. GPO. $0.20.

Recommendations for the Disposal of C-14 Wastes; NBS Handbook 53. GPO. $0.15.

Protection Against Radiations from Radium, Cobalt-60, and Cesium-137; NBS Handbook 54. GPO. $0.25.

Safe Handling of Cadavers Containing Radioactive Isotopes; NBS Handbook 56. GPO.

Photographic Dosimetry of X and Gamma Rays; NBS Handbook 57. GPO. $0.15.

Permissible Dose from External Sources of Ionizing Radiation; NBS Handbook 59. GPO. $0.35.

Safe Handling of Bodies Containing Radioactive Isotopes (A Guide for Surgeons, Pathologists, and Funeral Directors); NBS Handbook 65. GPO. $0.15.

Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air and in Water for Occupational Exposure; NBS Handbook 69. Issued June 5, 1959. GPO. $0.35.

Other must references are as follows

See radiation safety section pages 40-45 **Special Sources of Information on Isotopes,** TID-4563 (3rd Rev.); U.S. Atomic Energy Commission, Division of Isotopes Development, Washington 25, D.C.

Special Issue on Radioisotopes in Biological Research and Teaching **The American Biology Teacher;** Vol. 27, No. 6; August, 1965. Write to NABT P.O. Box 2113, Great Falls, Montana 59401 for information or copies of this issue.

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(Note: Books marked with an asterisk (*) should be acquired first.)

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American Journal of Physics, American Institute of Physics, 335 East 45th Street, New York, New York.

American Scientist, Sigma XI, 54 Hillhouse Avenue, New Haven 11, Connecticut.

Canadian Nature, Audubon Society of Canada, 181 Jarvis Street, Toronto 2, Canada.

Chemical and Engineering News, American Chemical Society, 1155 16th Street, N.W., Washington, D.C.

Cornell Rural School Leaflets, New York State College of Agriculture, Cornell University, Ithaca, New York.

Current Science and Aviation, American Education Press, 400 South Front Street, Columbus, Ohio.

Journal of Chemical Education, 20 and Northampton Streets, Easton, Pennsylvania.

Look and Listen, Britain's Audio-Visual Aids Journal, 62 Doughty Street, London, W.C.1

Mathematics Teacher, National Council of Teachers of Mathematics, 1201 16th Street, N.W., Washington, D.C.

National Geographic, National Geographic Society, 16th and M Streets, N.W., Washington, D.C.

Natural History, American Museum of Natural History, Central Park W. and 79th Street, New York.

Nature, Macmillan Company, St. Martin's Street, London, W.C.2

Popular Science Monthly, Popular Science Publishing Company, 353 Fourth Avenue, New York.

Review of Educational Research, American Educational Research Association, 1201 16th Street, N.W., Washington, D.C.

School Science and Mathematics, Box 408, Oak Park, Illinois.

School Science Review, S.W. Read, 31 Grosvenor Road, Chichester, Sussex, England.

Science, A.A.A.S., 1515 Massachusetts Avenue, N.W., Washington 5, D.C.

Science Counselor, Duquesne University, 901 Vickroy Street, Pittsburgh 19, Pennsylvania.

Science Education, National Association for Research in Science Teaching, University of Tampa, Tampa, Florida.

Science News Letter, Science Service, 1719 N. Street N.W., Washington 6, D.C.

The Science Teacher, National Science Teachers Association, 1201 16th Street N.W., Washington 6, D.C.

Scientific American, Scientific American, Inc., 415 Madison Avenue, New York 17, New York.

Sky and Telescope, Harvard Observatory, Cambridge 38, Massachusetts.

Turtox News, General Biological Supply House, 761 E. 69th Place, Chicago, Illinois.

World Science Review, 11 Easton Place, London, S.W.1

Weatherwise, American Meteorological Society, 3 Joy Street, Boston 8, Massachusetts.

Welch General Science and Biology Digest and **Welch Physics and Chemistry Digest,** W.M. Welch Scientific Company, 1515 North Sedgwick Street, Chicago 10, Illinois.

ORGANIZATIONS AND PUBLICATIONS

INTRODUCTION

The present day biology teacher will find that in order to keep abreast of current biological and educational research he needs to do professional reading. He also needs to attend professional meetings in order to converse with teachers and researchers. The administration should encourage and assist the teacher to attend local, state, regional and national organizational meetings. The classroom teacher should belong to the local, state, and at least one of the national organizations.

Teachers should consider membership in organizations which are in keeping with their area of specialization. (Example: *American Society of Ichthyologists and Herpetology*.)

A partial list is supplied with the realization that there exists numerous other organizations and publications.

BIOLOGY TEACHER ORGANIZATIONS AND PUBLICATIONS

a. *American Association For The Advancement of Science*, $10.00, **Science**, 1515 Massachusetts Avenue, N.W., Washington, D.C. 20005.

b. *American Institute of Biological Sciences*, $12.00, **Bio Science**, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016.

c. National Association of Biology Teachers, $8.00, **The American Biology Teacher**, P.O. Box 2113, Great Falls, Montana, 59401.

d. National Science Teachers Association, $8.00, **The Science Teacher**, 1201 Sixteenth Street, N.W., Washington, D.C. 20036.

e. National Wildlife Federation, **Wildlife**.

f. Science Teachers of Missouri, $3.00, **Missouri Science News**, Edith Link, Holts Summit, Missouri.

3. Associated Publications

a. **BSCS News Letter**, The Biological Sciences Curriculum Study, P.O. Box 930, Boulder, Colorado 80302. Free.

b. **Harvards Educational Review.**

c. **Journal of Research In Science Teaching.**

d. **Missouri Conservationist, The,** (Free to residents of Missouri), Missouri Conservation Commission, Jefferson City, Missouri.

e. **Natural History,** The American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. $5.00.

f. **Science Counselor, The,** Duquesne University Press, Pittsburg, Pennsylvania.

g. **Science Newsletter,** Science Service, 1719 New Street, N.W., Washington 6, D.C. $6.00

h. **Scientific American,** Scientific American, Inc., 2 West 45th Street, New York 36, New York. $6.00.

i. **Today's Health,** American Medical Association, $5.00.

TEACHER EDUCATION AND TRAINING

RECOMMENDATIONS

Although it is not the responsibility of this Committee to designate certification requirements for teachers of biology, it is clear some definite suggestions are appropriate. Throughout this report we have stressed emphasis on investigative work by the student under the guidance of his teacher. It is recognized that a new teacher tends to teach as he has been taught in college classes. College classes in science, often of necessity, leave out the independent, investigative approach. Basic science courses at the collegiate level are frequently designed to provide factual information for senior and post graduate courses. It is unfortunate that independent or guided investigations are not usually a part of a college student's preparation. Prospective teachers frequently take college courses which are not designed for their objectives. There is a definite move towards providing more independent student research at the undergraduate level. Since it is important that future teachers experience, as a student, the excitement of science in an atmosphere of inquiry, we strongly **recommend** that future teachers be provided with an opportunity **to do some independent research.** This opportunity may be provided in existing undergraduate courses carefully redesigned to utilize the principles outlined in this guide.

Finally, it is desirable that every teacher continue his biological training and own experiences in inquiry. Therefore, we **recommend that colleges and universities initiate summer study and research opportunities for teachers and that teachers be encouraged to participate in them frequently.**